1974

SOIL PLANT NUTRIENT RESEARCH REPORT

compiled by

K.S. McGill and J.L. Henry

Department of Soil Science
University of Saskatchewan
Saskatoon, Saskatchewan

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This report summarizes the field research investigations on soil fertility carried out during the 1974 season by the staff of the Department of Soil Science, University of Saskatchewan, Saskatoon. These investigations were supported by research funds provided from the following sources: The Saskatchewan Department of Agriculture, Canada Department of Agriculture, Western Co-operative Fertilizers Limited, Monsanto Limited, and Imperial Oil.

In soil fertility research, it is vital to conduct experiments under a wide variety of soil and climatic conditions. Almost all of the investigations were carried out on individual farms throughout the province. Without the generous cooperation of the many farmers involved, it would be impossible to conduct research of this type. A sincere thank you is extended to all farmers who put up with considerable inconvenience to accommodate these experiments.

All field operations associated with the placement of field plots including seeding, irrigation, routine maintenance and harvest were carried out by summer assistants including Laurie Tollefson, Paul Kneeshaw, Jack Richards and Richard Stusnoff as well as Mervin Manthey. Nitrogen, protein and oil analyses of plant material were performed by Denny Holben and Bob Ostafie of the Saskatchewan Soil Testing Laboratory. The laboratory also performed all routine soil analyses. Mass spectrometric analyses were performed by Lloyd Johns and Mervin Manthey with assistance from Paul Voroney and Mark Greenshields.

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INTRODUCTION

In 1971 a research project was initiated in the Outlook area of the South Saskatchewan River Irrigation Project with the following objectives:

1) To assess effects of nutrient levels, particularly of nitrogen, and irrigation scheduling on the yields and quality of a variety of crops including barley, soft wheat, rapeseed and alfalfa.

2) To provide guidelines on the fertilizer and water requirements for optimum production of these crops under irrigation.

3) To establish guidelines for target yield estimations.

During 1971 and 1972 major emphasis was placed on nitrogen nutrition of soft wheat, barley and rapeseed and phosphorus nutrition of alfalfa. In 1973, slight modifications were made to the experiments with cereals and rapeseed to provide further information on the effects of irrigation scheduling on yields of these crops. In 1974, the emphasis on work with cereals and rapeseed was switched to the irrigation scheduling topic and two major experiments were conducted to further evaluate the trend in the data that had been obtained in 1973. During 1974 work was also carried out on potatoes and corn. The corn experiments provided a useful demonstration of the benefits of nitrogen fertilization on the crop. However, due to poor harvest weather and inadequate handling facilities no meaningful yield data were obtained. The results of the experiment with potatoes are reported in a subsequent section.

Work with phosphate requirements of alfalfa during 1971 to 1973 showed very little yield response except in one location where levelling operations had completely removed the A horizon. As the phosphate fertilizers during those years had all been applied as a surface broadcast application on established stands, it was decided in 1974 to establish two experiments in which the phosphate was incorporated into the soil prior to seeding. In these experiments the phosphate applications were made and rototilled into the soil prior to seeding. However, the rototilling operations resulted in a seedbed that was not sufficiently firm for alfalfa and poor stands of alfalfa were obtained at both locations. It was therefore necessary to abandon both these experiments.

1.1 Nutrient and Water Requirements of Barley, Soft Wheat and Rapeseed

EXPERIMENTAL METHODS

For the crops barley, soft wheat and rapeseed two major experiments were layed down; one on an Elstow loam soil (Pederson farm) and the other on a Bradwell very fine sandy loam soil (Cameron farm). The Bradwell soil on the Cameron farm was very similar in composition to the Asquith very fine sandy loam soil on the Davison farm that had been utilized for major experiments through the years 1971 to 1973.

Soil analysis from samples taken at seeding time indicate very low nitrogen levels on the Bradwell soil with medium nitrogen levels on the Elstow soil (Table 1.1.1). It should also be noted that for the Elstow soil, particularly on the barley and rapeseed plots, substantial quantities of nitrogen were present in the 2 to 4 foot depth.

Table 1.1.1. Spring soil analyses for irrigation experiments.

Depth (inches)	N	P	K	pH	Cond. mmho/cm
	lbs/acre				
		ELSTOW: loam (Pederson site)			
		BARLEY			
0-6	5	26	900+	7.4	0.5
6-12	6	11	400	7.5	0.8
12-24	37	15	690	8.3	3.2
24-36	48	14	735	8.8	4.6
36-48	15	19	868	8.3	6.8
		SOFT WHEAT			
0-6	7	34	825	7.2	0.6
6-12	11	9	280	7.8	0.5
12-24	27	12	593	8.3	1.4
24-36	3	15	733	8.3	4.5
36-48	8	18	745	8.1	6.1
		RAPESEED			
0-6	8	23	900	7.3	0.4
6-12	8	9	301	7.4	0.4
12-24	20	6	520	8.1	0.9
24-36	33	6	575	8.4	2.9
36-48	10	10	643	8.2	3.9
		BRADWELL: very fine sandy loam (Cameron site)			
		BARLEY			
0-6	7	9	579	7.8	0.3
6-12	3	5	401	8.0	0.3
12-24	3	8	495	8.4	0.3
24-36	3	14	638	8.9	0.3
36-48	2	15	650	9.1	0.4
		SOFT WHEAT			
0-6	5	9	630	7.6	0.3
6-12	5	4	249	7.9	0.3
12-24	6	6	423	8.3	0.5
24-36	28	11	465	8.7	0.9
36-48	15	12	670	8.6	2.5
		RAPESEED			
0-6	3	10	698	7.7	0.2
6-12	3	3	270	8.0	0.3
12-24	3	6	463	8.4	0.3
24-36	13	12	593	8.9	0.4
36-48	14	14	590	8.9	0.8

Both experiments were placed on fields that had been croppped the previous year.

The cultivars used were Midas rapeseed, Springfield soft wheat and Betzes barley. The plots were rototilled prior to seeding with a double-disc press drill with seven rows per plot and a seven-inch row spacing. Plot length was 15 feet. Due to the excessive rainfall during the month of May seeding operations were not completed until May 29th on the Bradwell soil and May 30th on the Elstow soil.

Phosphate applications with the seed were made to all plots at a rate of 40 lbs P_2O_5/acre with barley and soft wheat and 30 lbs P_2O_5/acre with rapeseed. Monoammonium phosphate (11-55-0) was used as the phosphate source throughout. The fertility treatments included a range of nitrogen rates from 0 to 200 lbs N/acre (Table 1.1.2). All nitrogen was applied as a surface broadcast application of ammonium nitrate (34-0-0) applied at the time of seeding.

Avadex was used as a preplant application on barley and Treflan was applied preplant on rapeseed. Post-emergent herbicides included TOK-RM for rapeseed, Buctril-M for wheat and TCA and MCPA for barley.

Severe infestations of flea beetles on the rapeseed necessitated two sprayings with malathion. It was also necessary to use malathion and hopper-tox for grasshopper control on all crops on the Bradwell soil.

For the irrigation scheduling portion of these experiments four water schedules were utilized (Table 1.1.2). In water schedule A the first irrigation was deleted, in water schedule B the second irrigation was deleted, in water schedule C the third irrigation was deleted whereas water schedule D received all irrigations.

Table 1.1.2. Fertility and water treatments used in irrigation experiments.

Fertility Treatment Number	Nitrogen Applied (lbs/acre)
1	0
2	50
3	75
4	100
5	150
6	200

Note: Barley and soft wheat also received 40 lb P_2O_5/acre. Rapeseed also received 30 lb P_2O_5/acre. All phosphate was seed placed.

Water Schedule	Treatment
A	Missed first irrigation
B	Missed second irrigation
C	Missed third irrigation
D	Received all irrigations

Table 1.1.3. Depth of water required to replenish soil moisture in irrigation experiments.

Deep Tensiometer Reading	Depth of water in inches	
	Elstow soil	Bradwell soil
0.3	2.5	2.0
0.3 - 0.7	3.5	
greater than 0.7	4.5	4.0

The actual scheduling of irrigation was determined by tensiometers. Shallow tensiometers were installed at the 4 to 6 inch level initially and then moved down to the 6 to 9 inch level in late June. Deeper tensiometers were installed initially at the 10 to 12 inch depth and moved down to the 16 to 18 inch depth in late June. The shallow tensiometers were installed in fertility treatment three of all water treatments and in all four replicates. The deeper tensiometers were installed only in replicate three of fertility treatment three in all water treatments.

The tensiometers were utilized to determine both the timing of irrigation and the amount to apply. Irrigation water was applied when the shallow tensiometers indicated a soil moisture tension of 0.5 atm for both soils. The amount of water to apply was determined by the readings obtained on the deep tensiometers as indicated in Table 1.1.3 (page 5).

Neutron access tubes were installed to a depth of 4 feet in fertility treatment three of all replicates and all water treatments. Moisture monitoring was then conducted with the neutron probe except for the 0 to 6 inch depth which was done gravimetrically. Moisture measurements were made at the time of installation at seeding time, one day before and two days after each irrigation and again at harvest time.

Irrigation water was applied through the use of a custom designed sprinkler system which allowed separate timing and amounts of water to the various irrigation scheduling treatments under study. The timing and amounts of irrigation water applied are presented in Table 1.1.4.

Table 1.1.4. Amounts and timing of irrigation applications.

Crop and Water Schedule				Total Water (Irrig. + Rain) (inches)
		Elstow soil (Pederson)		
		Growing Season Rainfall 5.5"		
Barley				
A		July 17, 3.2"	July 29, 3.4"	12.1
B	June 27, 3.4"		July 28, 3.4"	12.3
C	June 27, 3.4"	July 17, 3.2"		12.1
D	July 2, 3.0"	July 17, 3.2"	July 28, 3.4"	15.1
Soft Wheat				
A		July 16, 3.3"	July 28, 3.1"	11.9
B	June 27, 3.4"		July 28, 3.1"	12.0
C	June 27, 3.4"	July 16, 3.3"		12.2
D	July 2, 3.6"	July 16, 3.3"	July 28, 3.1"	15.5
Rapeseed				
A		July 16, 3.1"	July 28, 3.7"	12.3
B	June 27, 3.3"		July 28, 3.7"	12.5
C	June 27, 3.3"	July 16, 3.1"		11.9
D	July 2, 3.2"	July 16, 3.1"	July 28, 3.7"	15.5
		Bradwell soil (Cameron)		
		Growing Season Rainfall 5.8"		
Barley				
A		Aug. 8, 3.2"		9.0
B	July 24, 2.6"			8.4
C and D	July 24, 2.6"	Aug. 8, 3.2"		11.6
Soft Wheat				
A		July 24, 2.4"	Aug. 8, 3.5"	11.7
B	July 6, 3.0"		Aug. 8, 3.5"	12.3
C	July 6, 3.0"	July 24, 2.4"		11.2
D	July 6, 3.0"	July 24, 2.4"	Aug. 8, 3.5"	14.7
Rapeseed				
A		July 24, 2.5"	Aug. 8, 3.3"	11.6
B	July 8, 3.2"		Aug. 8, 3.3"	12.3
C	July 8, 3.2"	July 24, 2.5"		11.5
D	July 8, 3.2"	July 24, 2.5"	Aug. 8, 3.3"	14.8

At harvest, yield samples were taken from all treatments by clipping at the soil surface the three center rows of the seven-row plot over a length of ten feet. The samples were then dried, threshed and weighed. Subsamples of both grain and straw were taken, replicates of individual treatments from each plot were composited, mixed and ground. Analyses were performed for percent nitrogen content of the straw, percent protein content of the grain and in the case of rapeseed, percent oil content of the seed (unground).

RESULTS AND DISCUSSION

Response of Barley, Soft Wheat and Rapeseed to Nitrogen Fertilization

Data on the effect of nitrogen fertilization on the yield, protein content and nitrogen uptake of soft wheat, barley and rapeseed and oil content of rapeseed are present in Tables 1.1.5 to 1.1.10. For the Bradwell soil where soil nitrogen levels were very low all three crops responded strongly to applied nitrogen, particularly in water treatments C and D where little or no moisture stress had been allowed. For water treatment A, where the first irrigation was missed resulting in a moisture stress early in the growing season, the responses to nitrogen were greatly reduced.

For the Bradwell soil the effect of nitrogen on protein content of all three crops was similar to that observed in previous years on soils testing very low in nitrogen. For the water A and water B treatments where yield increases were relatively low, sharp increases in protein resulted from the addition of nitrogen. For water treatments C and D where yield increases were substantial, nitrogen additions had little effect on protein content at the 50 lb N/acre rate. At

Table 1.1.5. The effect of nitrogen fertilization and irrigation scheduling on the yield, nitrogen content and nitrogen uptake of Betzes barley grown on Bradwell soil (Cameron site).

N Applied lb/ac	Yield: Grain bu/ac	Yield: Straw lb/ac	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake (lb/acre): Grain	Nitrogen Uptake (lb/acre): Straw	Nitrogen Uptake (lb/acre): Total
				WATER A				
0	10.6	487	1.04	7.5	0.44	6.1	2.1	8.2
50	18.9	1217	0.73	9.8	0.54	14.3	6.6	20.9
75	23.8	1460	0.79	11.5	0.72	21.1	10.5	31.6
100	24.9	1721	0.70	13.4	0.92	25.6	15.8	41.4
150	18.7	2065	0.44	15.1	1.04	21.6	21.5	43.1
200	25.8	1716	0.72	15.8	1.24	31.3	21.3	52.6
				WATER B				
0	11.5	525	0.97	7.4	0.32	6.5	1.7	8.2
50	36.7	1719	1.02	7.9	0.50	22.2	8.6	30.8
75	29.1	1635	0.90	9.1	0.59	20.3	9.6	29.9
100	39.5	1999	1.01	10.7	0.61	32.4	12.2	44.6
150	51.4	2255	1.13	12.8	0.75	50.3	16.9	67.2
200	46.9	1959	1.18	13.1	0.90	47.2	17.6	64.8
				WATER C				
0	15.4	762	0.96	7.8	0.53	9.2	4.0	13.2
50	35.0	2356	0.75	7.8	0.42	21.0	9.9	30.9
75	42.9	2498	0.87	9.1	0.66	30.0	16.5	46.5
100	61.6	3028	1.04	10.1	0.50	47.9	15.1	63.0
150	61.3	3633	0.82	10.5	0.67	49.6	24.3	73.9
200	62.6	3734	0.81	12.9	0.80	62.0	29.9	91.9
				WATER D				
0	20.7	1089	0.91	8.9	0.51	14.2	5.6	19.8
50	26.8	1872	0.73	8.6	0.41	17.6	7.7	25.3
75	36.8	2382	0.78	9.0	0.55	25.5	13.1	38.6
100	37.7	2388	0.79	8.3	0.52	24.1	12.4	36.5
150	69.2	3641	0.94	12.2	0.58	64.6	21.1	85.7
200	68.8	3817	0.86	12.5	0.85	66.0	32.4	98.4
L.S.D. (.05)	12.8	724	0.30					

[1]Grain protein content based on % N at 13.5% moisture x 6.25 straw % N on ovendry basis.

Table 1.1.6. The effect of nitrogen fertilization and irrigation scheduling on the yield, nitrogen content and nitrogen uptake of Betzes barley grown on Elstow soil (Pederson site).

N Applied lb/ac	Yield: Grain bu/ac	Yield: Straw lb/ac	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake (lb/acre): Grain	Nitrogen Uptake (lb/acre): Straw	Nitrogen Uptake (lb/acre): Total
				WATER A				
0	70.2	3496	0.98	11.4	0.67	61.4	23.4	84.8
50	74.9	4385	0.82	11.9	0.83	68.7	36.4	105.1
75	76.1	4636	0.79	11.7	1.11	68.3	51.5	119.8
100	79.2	4503	0.85	12.1	1.12	73.3	50.4	123.7
150	78.0	4585	0.84	12.8	1.30	76.4	59.6	136.0
200	72.1	4423	0.79	12.7	1.27	70.3	56.2	126.5
				WATER B				
0	74.4	4877	0.74	11.5	0.67	65.7	32.7	98.4
50	70.8	4601	0.75	11.7	0.74	63.6	34.0	97.6
75	86.4	5067	0.82	12.0	0.74	79.6	37.5	117.1
100	87.0	6062	0.71	11.7	0.98	78.2	54.4	132.6
150	68.2	5026	0.66	12.4	1.20	64.9	60.3	125.2
200	65.5	4729	0.66	13.1	1.25	65.9	59.1	125.0
				WATER C				
0	78.5	4616	0.82	12.6	0.95	76.0	43.9	119.9
50	86.8	5247	0.80	12.4	0.81	82.7	42.5	125.2
75	83.7	5962	0.69	13.2	1.11	84.9	66.2	151.1
100	91.9	5491	0.84	12.7	1.09	89.6	59.9	149.5
150	91.5	5516	0.80	13.4	1.44	94.2	79.4	173.6
200	87.3	5525	0.76	13.7	1.51	91.9	83.4	175.3
				WATER D				
0	90.6	5145	0.86	13.3	0.88	92.5	45.3	137.8
50	106.3	5248	0.98	12.9	0.89	105.3	46.7	152.0
75	94.0	5725	0.81	13.0	1.09	93.8	62.4	156.2
100	106.6	5965	0.87	12.9	0.97	105.6	57.9	163.5
150	91.6	5890	0.75	13.5	1.20	95.0	70.7	165.7
200	93.1	6176	0.74	13.5	1.31	96.5	80.9	177.4
L.S.D. (.05)	14.3	1055	0.18					

[1]Grain protein content based on % N at 13.5% moisture x 6.25 straw % N on ovendry basis.

Table 1.1.7. The effect of nitrogen fertilization and irrigation scheduling on the yield, nitrogen content and nitrogen uptake of Springfield soft wheat grown on Bradwell soil (Cameron site).

N Applied lb/ac	Yield		Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Nitrogen Uptake (lb/acre)		
	Grain bu/ac	Straw lb/ac				Grain	Straw	Total
				WATER A				
0	17.8	1336	0.79	7.8	0.51	14.7	6.8	21.5
50	22.7	2399	0.57	8.7	0.54	20.9	13.0	33.9
75	22.2	2608	0.52	9.2	0.59	21.4	15.4	36.8
100	24.3	3007	0.50	10.4	0.73	26.7	22.0	48.7
150	26.6	2965	0.54	11.6	0.97	32.6	28.8	61.4
200	24.8	2866	0.52	12.2	1.06	32.0	30.4	62.4
				WATER B				
0	16.5	1215	0.82	7.6	0.49	13.2	6.0	19.2
50	27.0	2949	0.56	8.3	0.48	23.5	14.2	37.7
75	25.0	3105	0.51	8.8	0.57	23.2	17.7	40.9
100	29.3	3562	0.50	10.0	0.61	30.8	21.7	52.5
150	27.7	3308	0.50	12.5	1.02	36.5	33.7	70.2
200	24.1	3305	0.44	13.0	1.09	33.0	36.0	69.0
				WATER C				
0	15.1	1308	0.69	8.4	0.53	13.3	6.9	20.2
50	36.0	3501	0.62	7.5	0.46	28.6	16.1	44.7
75	33.9	3790	0.55	8.7	0.64	31.2	24.3	55.5
100	37.3	4069	0.55	8.2	0.72	32.2	29.3	61.5
150	36.4	4056	0.53	9.8	0.85	37.5	34.5	72.0
200	38.6	4093	0.57	10.3	1.02	41.9	41.7	83.6
				WATER D				
0	18.0	1423	0.75	8.7	0.46	16.4	6.5	22.9
50	30.0	3039	0.60	7.3	0.41	23.1	12.5	35.6
75	35.4	3681	0.57	8.2	0.53	30.7	19.5	50.2
100	37.8	4152	0.54	9.1	0.59	36.3	24.5	60.8
150	37.5	4323	0.54	9.7	0.92	38.3	39.8	78.1
200	28.5	4055	0.42	9.5	0.92	28.6	37.3	65.9
L.S.D. (.05)	7.7	617	0.12					

[1] Grain protein content based on % N at 13.5% moisture x 5.7 straw % N on ovendry basis.

Table 1.1.8. The effect of nitrogen fertilization and irrigation scheduling on the yield, nitrogen content and nitrogen uptake of Springfield soft wheat grown on Elstow soil (Pederson site).

N Applied lb/ac	Yield Grain bu/ac	Yield Straw lb/ac	Grain/ Straw Ratio	Grain % Protein	Straw % N	Nitrogen Uptake Grain (lb/acre)	Nitrogen Uptake Straw (lb/acre)	Nitrogen Uptake Total (lb/acre)
				WATER A				
0	26.3	1585	0.99	10.8	0.87	29.9	13.8	43.7
50	30.4	2065	0.89	11.5	0.88	36.8	18.2	55.0
75	25.2	1751	0.88	11.6	0.97	30.6	17.0	47.6
100	30.7	2113	0.88	11.9	1.10	38.5	23.2	61.7
150	33.0	2264	0.90	11.6	1.10	40.1	24.9	65.0
200	26.9	1976	0.83	12.0	1.11	34.0	21.9	55.9
				WATER B				
0	45.6	3176	0.87	9.4	0.73	45.1	23.2	68.3
50	39.4	3131	0.76	10.1	0.89	41.9	27.9	69.8
75	38.6	3241	0.72	10.7	0.97	43.5	31.4	74.9
100	37.1	3263	0.69	10.5	1.00	41.0	32.6	73.6
150	37.0	3091	0.72	11.4	1.08	44.4	33.4	77.8
200	36.5	3302	0.67	11.3	1.17	43.4	38.6	82.0
				WATER C				
0	47.5	3579	0.80	9.9	0.65	49.5	23.3	72.8
50	47.9	3961	0.73	12.7	0.93	64.0	36.8	100.8
75	45.8	4235	0.65	12.7	1.02	61.2	43.2	104.4
100	42.6	4232	0.62	13.8	1.32	61.9	55.9	117.8
150	43.6	4380	0.60	13.2	1.18	60.6	51.7	112.3
200	41.6	4416	0.57	12.7	1.37	55.6	60.5	116.1
				WATER D				
0	39.4	3010	0.79	9.4	0.76	39.0	22.9	61.9
50	39.3	3254	0.72	10.8	0.97	44.7	31.6	76.3
75	39.9	3494	0.69	11.4	1.04	47.9	36.3	84.2
100	44.3	3961	0.68	11.6	1.06	54.1	42.0	96.1
150	41.0	3810	0.65	11.8	1.30	50.9	49.5	100.4
200	38.8	3422	0.69	11.5	1.37	47.0	46.9	93.9
L.S.D. (.05)	6.9	621	0.11					

[1]Grain protein content based on % N at 13.5% moisture x 5.7 straw % N on ovendry basis.

Table 1.1.9. The effect of nitrogen fertilization and irrigation scheduling on the yield, nitrogen content, oil content and nitrogen uptake of Midas rapeseed grown on Bradwell soil (Cameron site).

N Applied lb/ac	Yield Grain bu/ac	Yield Straw lb/ac	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Grain % Oil	Nitrogen Uptake Grain (lb/acre)	Nitrogen Uptake Straw (lb/acre)	Nitrogen Uptake Total (lb/acre)
				WATER A					
0	10.4	1563	0.33	17.5	0.53	46.0	14.5	8.3	22.8
50	18.6	2790	0.33	17.9	0.51	45.8	26.6	14.2	40.8
75	19.4	3276	0.29	19.3	0.71	44.3	30.0	23.3	53.3
100	20.5	3359	0.31	20.4	0.74	43.5	33.5	24.8	58.3
150	20.2	3252	0.31	22.0	1.03	42.2	35.4	33.5	68.9
200	12.6	2109	0.29	21.6	0.95	42.8	21.8	20.0	41.8
				WATER B					
0	11.1	1921	0.29	17.5	0.64	46.5	15.5	12.3	27.8
50	19.8	3373	0.29	19.0	0.57	45.6	30.1	19.2	49.3
75	14.7	2894	0.25	20.8	0.85	44.2	24.4	24.6	49.0
100	15.9	3144	0.25	21.8	0.90	42.5	27.8	28.3	56.1
150	16.0	3314	0.24	22.1	0.99	42.5	28.1	32.8	60.9
200	17.7	3283	0.27	22.8	1.23	41.7	32.3	40.4	72.7
				WATER C					
0	13.6	3068	0.24	17.5	0.64	46.5	19.1	19.6	38.7
50	23.9	4343	0.28	16.7	0.62	46.9	32.0	26.9	58.9
75	22.1	4684	0.24	19.3	0.67	44.6	34.0	31.4	65.4
100	26.1	4429	0.30	19.5	0.90	44.4	40.6	39.9	80.5
150	30.8	4743	0.32	20.5	1.06	43.3	50.4	50.3	100.7
200	28.3	4395	0.32	20.6	1.39	42.6	46.6	61.1	107.7
				WATER D					
0	14.7	2298	0.32	17.4	0.59	46.8	20.5	13.6	34.1
50	26.0	3799	0.34	18.0	0.67	46.5	37.6	25.4	63.0
75	28.4	4397	0.32	19.7	0.81	44.3	44.7	35.6	80.3
100	27.1	4711	0.30	20.2	0.84	42.9	43.7	39.6	83.3
150	30.5	4891	0.31	20.4	1.29	42.8	49.9	63.1	113.0
200	31.9	4897	0.33	20.3	1.30	42.6	51.6	63.6	115.2
L.S.D. (.05)	7.3	1164	0.04						

[1]Grain protein content based on % N at 13.5% moisture x 6.25 straw % N on ovendry basis.

Table 1.1.10. The effect of nitrogen fertilization and irrigation scheduling on the yield, nitrogen content, oil content and nitrogen uptake of Midas rapeseed grown on Elstow soil (Pederson site).

N Applied lb/ac	Yield Grain bu/ac	Yield Straw lb/ac	Grain/ Straw Ratio	Grain[1] % Protein	Straw % N	Grain % Oil	Nitrogen Uptake Grain (lb/acre)	Nitrogen Uptake Straw (lb/acre)	Nitrogen Uptake Total (lb/acre)
				WATER A					
0	25.6	3243	0.39	19.9	0.95	44.0	40.8	30.8	71.6
50	29.1	4378	0.34	21.3	1.15	43.3	49.5	50.3	99.8
75	22.2	3213	0.34	21.8	1.10	43.0	38.7	35.3	74.0
100	32.1	4624	0.34	20.2	1.20	42.3	51.7	55.5	107.2
150	28.3	4206	0.34	21.7	1.23	42.0	49.1	51.7	100.8
200	25.5	4060	0.31	20.4	1.48	42.6	41.6	60.1	101.7
				WATER B					
0	24.1	3189	0.37	18.0	0.67	45.8	34.7	21.4	56.1
50	22.7	3258	0.35	18.0	0.95	45.2	32.7	31.0	63.7
75	26.5	3430	0.39	19.6	1.09	42.8	41.6	37.4	79.0
100	31.2	3732	0.42	20.9	1.16	42.6	52.2	43.3	95.5
150	27.5	3749	0.36	21.3	1.36	42.2	46.9	51.0	97.9
200	24.8	3533	0.36	21.2	1.39	42.6	42.1	49.1	91.2
				WATER C					
0	28.0	3724	0.36	19.8	0.78	46.5	44.4	29.0	83.4
50	32.1	3968	0.39	17.9	0.86	45.2	46.0	34.1	80.1
75	25.8	3646	0.35	21.0	0.88	43.5	43.3	32.1	75.4
100	27.0	3990	0.32	20.2	0.97	44.0	43.6	38.7	82.3
150	33.9	4506	0.36	21.6	1.20	43.5	58.6	54.1	112.7
200	33.9	4562	0.37	20.1	1.27	43.8	54.5	57.9	112.4
				WATER D					
0	32.8	4771	0.34	17.8	0.74	45.8	46.7	35.3	82.0
50	31.6	4751	0.33	20.6	0.81	44.8	52.1	38.5	90.6
75	26.3	4382	0.29	20.1	0.87	44.7	42.3	38.1	80.4
100	44.5	6401	0.35	20.7	1.10	44.8	73.7	70.4	144.1
150	33.5	5470	0.30	20.6	0.99	44.0	55.2	54.2	109.4
200	28.4	4467	0.32	21.5	1.14	43.7	48.8	50.9	99.7
L.S.D. (.05)	11.6	1277	0.07						

[1]Grain protein content based on % N at 13.5% moisture x 6.25 straw % N on ovendry basis.

rates of nitrogen in excess of 100 lbs N/acre increases in protein content occurred for soft wheat and barley. With rapeseed the 75 lb N/acre rate and rates in excess of this resulted in sharp increases in the protein content and very sharp reductions in the oil content. For the water D treatment the oil content of rapeseed dropped from 46.8% when no nitrogen was applied to 42.6% when 200 lbs N/acre were applied (Table 1.1.9).

For the Elstow soil (Tables 1.1.6, 1.1.8 and 1.1.10) where the soil nitrogen level was in the medium to high range, very few significant responses to nitrogen were obtained. For the water C and water D treatments of rapeseed and barley small yield increases were apparent, although the response curves were highly variable. With soft wheat there were no significant yield increases. For the water B and water C treatments of soft wheat there were actually significant grain yield decreases. The reason for this apparently anomalous result is not known at this time. Small but significant yield reductions to nitrogen fertilization have been obtained on two previous occasions within the irrigation area. However, the earlier results were obtained on soils testing very high in nitrogen and under conditions where possible moisture stresses were suspected. The grain yield reduction, together with a small straw yield increase resulted in a very sharp reduction in the grain/straw ratio due to nitrogen fertilization (Table 1.1.8).

For the Elstow soil nitrogen fertilization had relatively little effect on the protein content of barley. For soft wheat, a large increase in the protein content was obtained for the water C treatment, with somewhat lesser increases occurring for the other water treatments.

With rapeseed, the protein content was increased by nitrogen fertilization, particularly for rates of nitrogen in excess of 50 lbs N/acre. As was the case with the Bradwell soil, nitrogen additions resulted in very significant reductions in the oil content of rapeseed. For the water B and water C treatments, the oil contents were quite similar at both sites for all rates of nitrogen utilized.

Effects of Irrigation Scheduling

As indicated previously, a major objective of this research was to determine the effects of irrigation scheduling on yields of the crops under study. The irrigation treatments used and water applications made have been presented in the previous section (Tables 1.1.2, 1.1.3 and 1.1.4).

The seasonal water use patterns show slightly increased total water use for rapeseed as compared to soft wheat and barley (Table 1.1.11). The water use pattern of soft wheat and barley was quite similar.

For both soils the total water use of the water D treatment exceeded that of all other treatments and for the Elstow soil this difference was as much as 5.4 inches. It is interesting to note that for the Elstow soil the increased total water use of the water D treatment is due in part to somewhat greater extraction of soil moisture. The full interpretation of that observation is made difficult due to the fact that the first irrigation on the water D treatment for the Elstow soil was delayed about one week due to excessive wind conditions.

The relative rating of yields from the various irrigation schedules (Table 1.1.12) show clearly the importance of starting the irrigation operations early. For all crops at both locations the water A treatment (which missed the first irrigation) gave the lowest yields.

Table 1.1.11. Seasonal water use of barley, soft wheat and rapeseed.

Crop	Water Schedule	Rainfall + Irrigation	ΔS*	Total Water Use**
		inches		
		Elstow soil (Pederson site) (Rain = 5.5")		
Barley	A	12.1	0.6	12.7
	B	12.3	0.2	12.6
	C	12.1	1.6	13.7
	D	15.1	2.3	17.4
Soft Wheat	A	11.9	0.2	12.1
	B	12.0	0.1	12.1
	C	12.2	1.6	13.8
	D	15.5	2.0	17.5
Rapeseed	A	12.3	1.7	14.0
	B	12.5	1.7	14.2
	C	11.9	1.4	13.3
	D	15.5	2.8	18.3
		Bradwell soil (Cameron site) (Rain = 5.8")		
Barley	A	9.0	0.3	9.3
	B	8.4	2.5	10.9
	C	11.6	0.2	11.8
	D	11.6	0.7	12.3
Soft Wheat	A	11.7	0.2	11.9
	B	12.3	-0.2	12.1
	C	11.2	0.8	12.0
	D	14.7	-0.5	14.2
Rapeseed	A	11.6	0.5	12.1
	B	12.3	0.7	13.0
	C	11.5	2.5	14.0
	D	14.8	0.1	14.9

* ΔS = change in soil moisture content (spring-fall).

**Total water use = rainfall + irrigation + ΔS.

Table 1.1.12. Relative rating of yields from various irrigation regimes.

	Bradwell soil (Cameron site)	Elstow soil (Pederson site)
Barley	A[1] < B[2] < C = D	A = B < C < D[3]
Soft Wheat	A < B < C = D	A < B < C B = D
Rapeseed	A = B < C < D	A = B < C = D

[1] Water A = missed the first irrigation

Water B = missed the second irrigation

Water C = missed the third irrigation

Water D = received all irrigations

[2] The symbol < is read "yielded less than"

[3] For the Elstow soil the first irrigation on water D was delayed about one week from when it was required according to tensiometer readings.

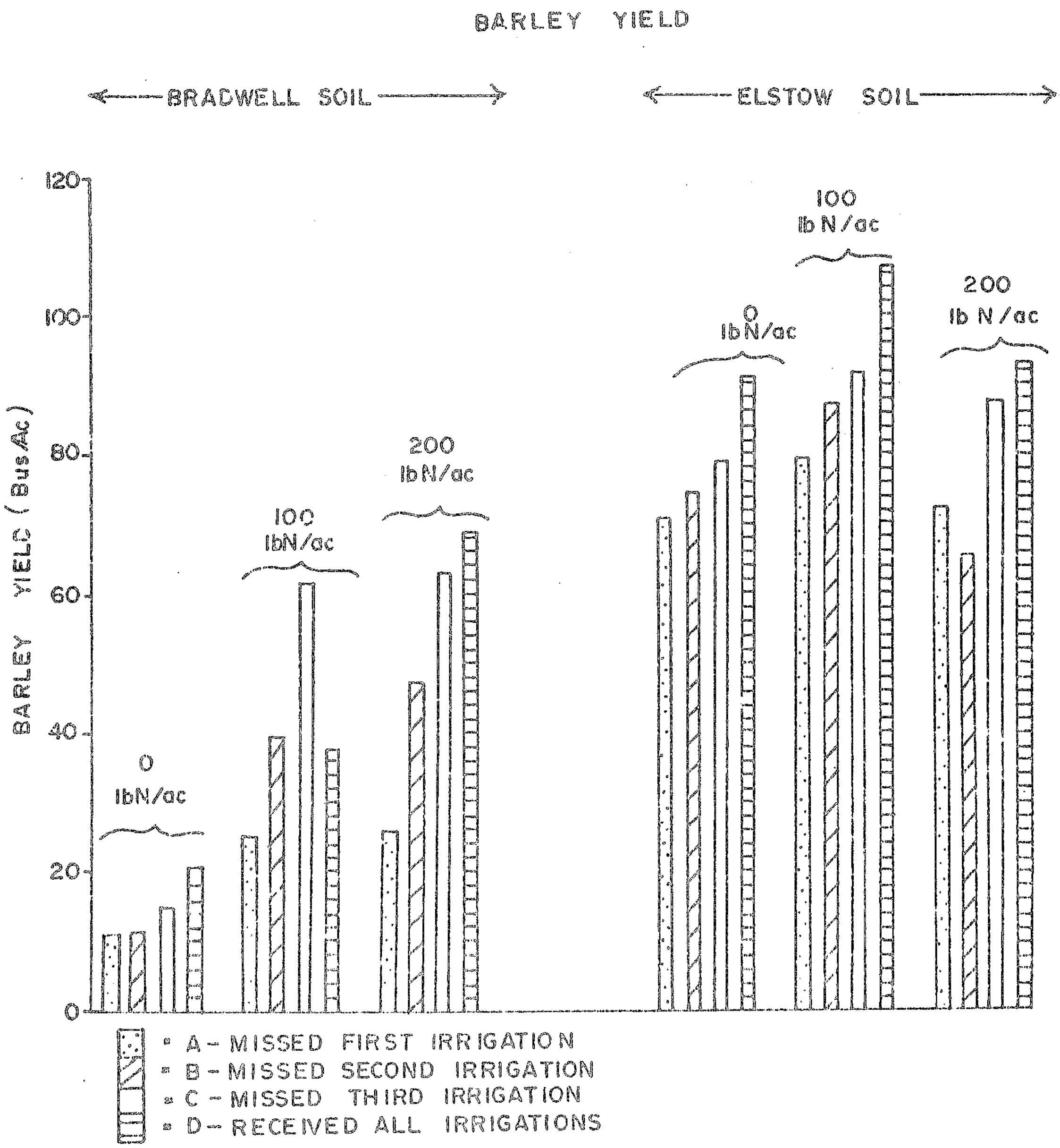
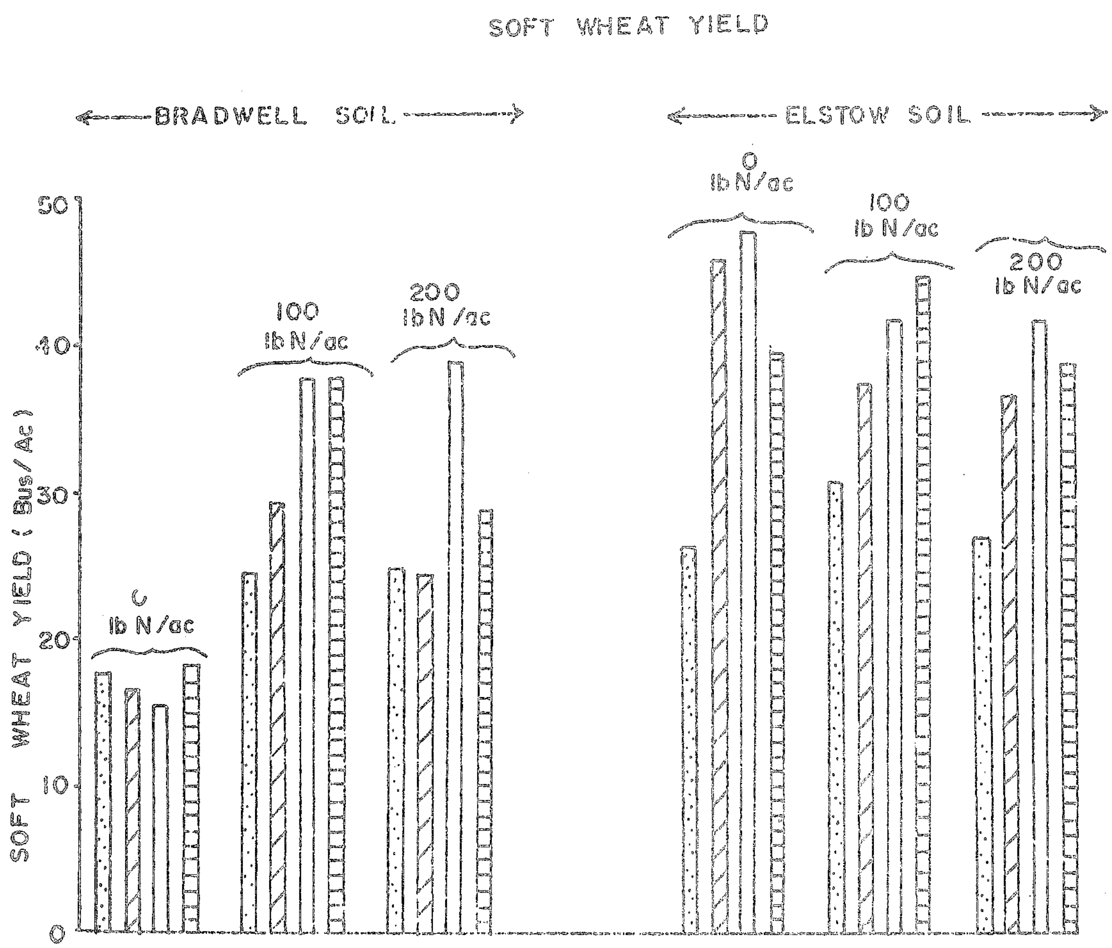


Fig I.I.I THE EFFECT OF DIFFERENT MOISTURE STRESSES ON THE YIELD OF BARLEY WITH DIFFERENT RATES OF NITROGEN



A - MISSED FIRST IRRIGATION
B - MISSED SECOND IRRIGATION
C - MISSED THIRD IRRIGATION
D - RECEIVED ALL IRRIGATIONS

Fig I.1.2 THE EFFECT OF DIFFERENT MOISTURE STRESSES ON THE YIELD OF SOFT WHEAT WITH DIFFERENT RATES OF NITROGEN

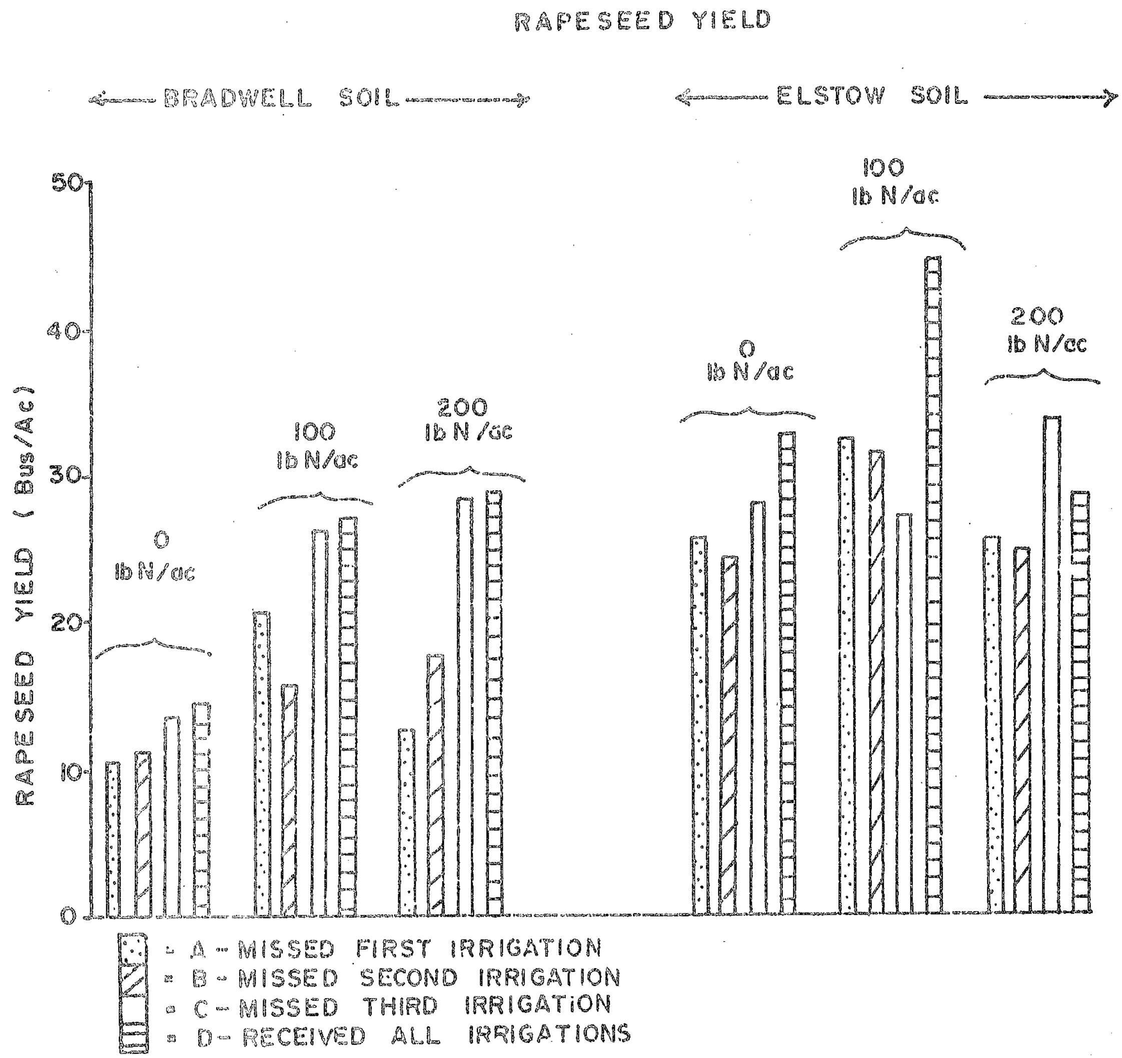


Fig 1.1.3 THE EFFECT OF DIFFERENT MOISTURE STRESSES ON THE YIELD OF RAPESEED WITH DIFFERENT RATES OF NITROGEN

Further data on the effects of irrigation scheduling on the yield of the three crops under study is provided in Figures 1.1.1, 1.1.2 and 1.1.3. For barley, there is a general pattern of increasing yields in moving a moisture stress from early in the season to late in the season. The absolute increases in yield were quite low for the Bradwell soil where no additional nitrogen was supplied, whereas for the 200 lb N/acre treatment irrigation scheduling resulted in a 300% increase in yields. The results for soft wheat and rapeseed are essentially the same as for wheat. The very large yield increases due to late applications of water on rapeseed that have been reported by workers at Agriculture Canada Research Station in Lethbridge are not apparent in the data presented herein.

The effects of irrigation scheduling on the protein content of barley, soft wheat and rapeseed are presented in Figures 1.1.4, 1.1.5 and 1.1.6, respectively.

For the barley on the Bradwell soil (Figure 1.1.4) where the soil N level was very low and where no additional nitrogen was applied, moisture stresses throughout the growing season actually appeared to reduce protein slightly. However, where 100 or 200 lbs N/acre were added the stresses throughout the growing season resulted in very large increases in the protein content, with the moisture stress at the earliest stage resulting in the largest increase in protein content. For the Elstow soil where the soil nitrogen levels were more nearly adequate the moisture stresses through the season had relatively less effect on the protein content of barley.

For soft wheat (Figure 1.1.5), the data for the Bradwell soil were similar to barley. For the Elstow soil a stress in mid

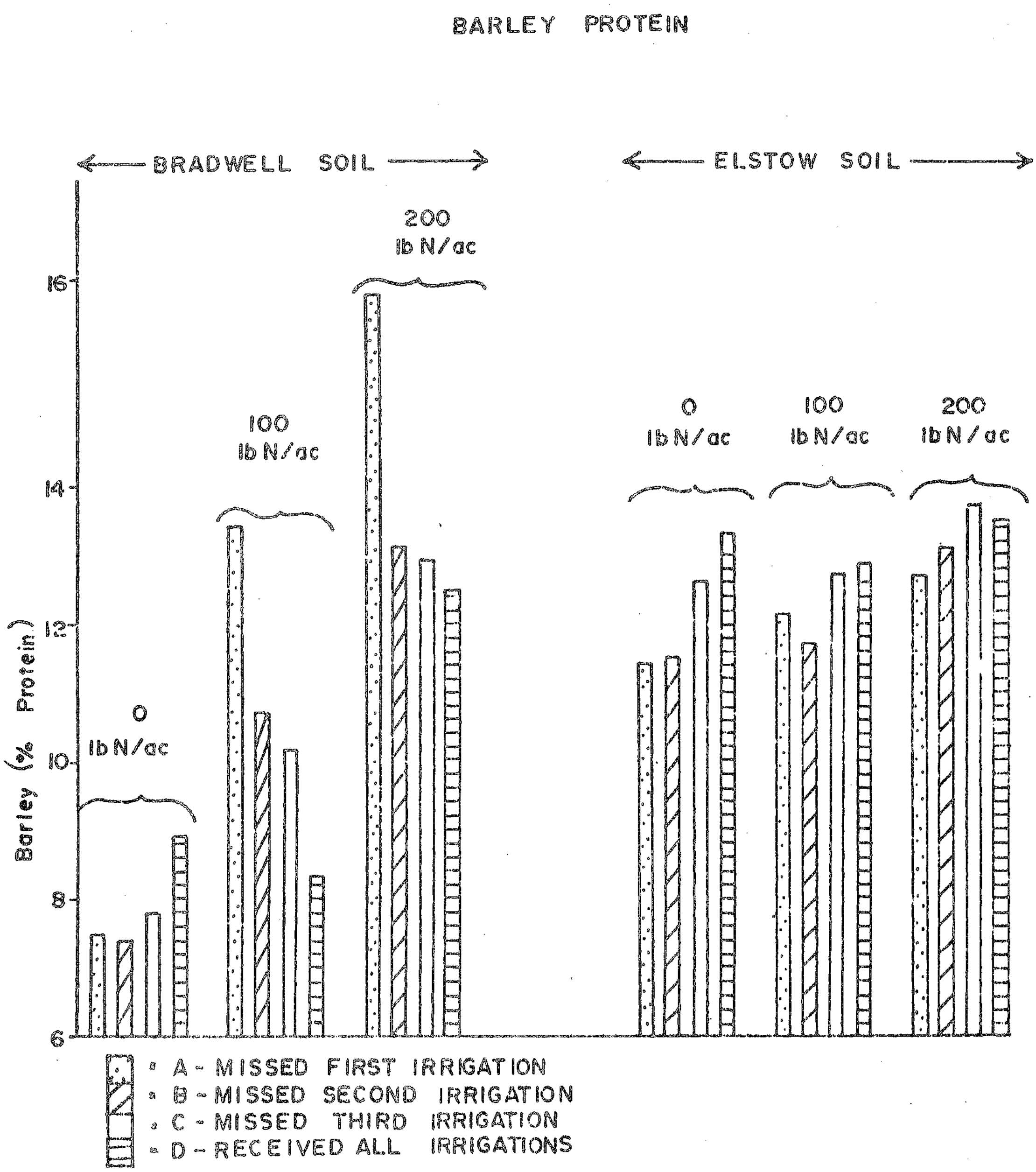


Fig. 1.1.4 THE EFFECT OF DIFFERENT MOISTURE STRESSES ON THE PROTEIN CONTENT OF BARLEY WITH DIFFERENT RATES OF NITROGEN

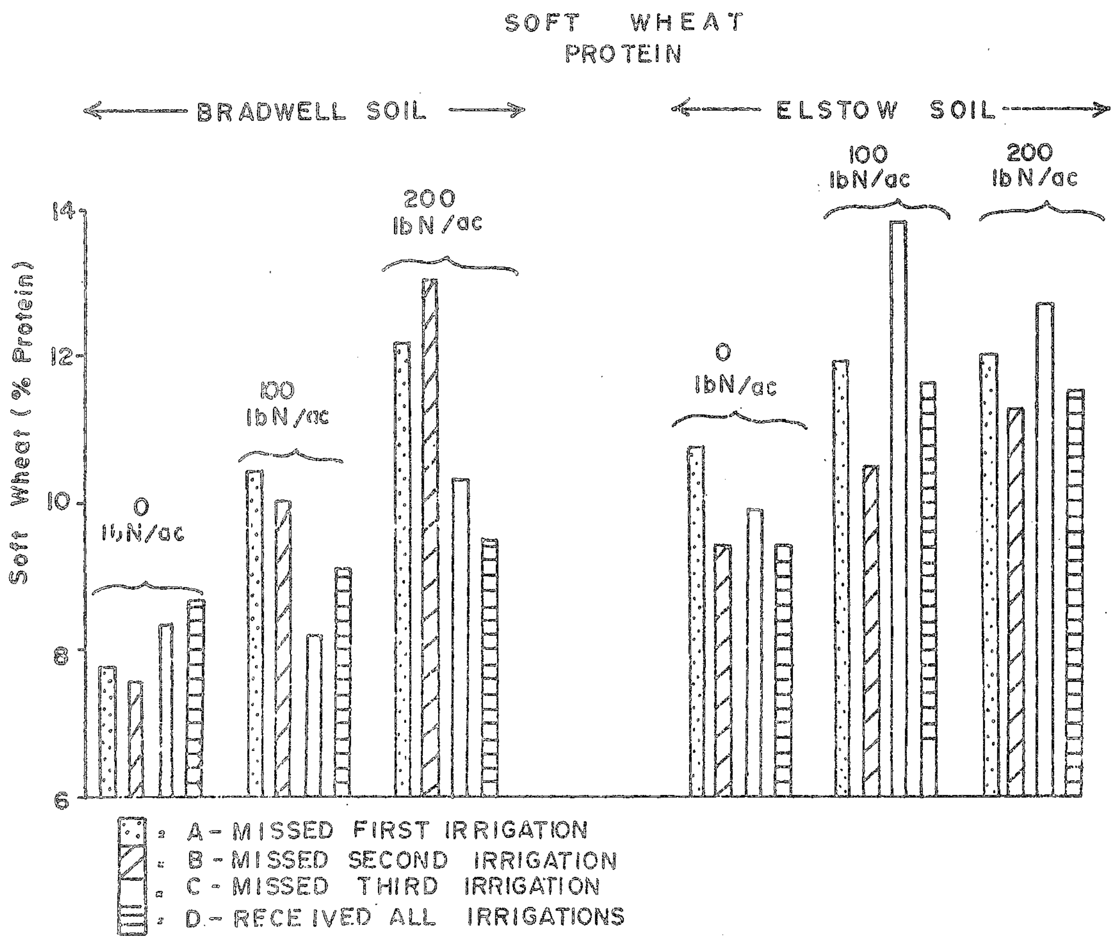


Fig I.I.5 THE EFFECT OF DIFFERENT MOISTURE STRESSES ON THE PROTEIN CONTENT OF SOFT WHEAT WITH DIFFERENT RATES OF NITROGEN

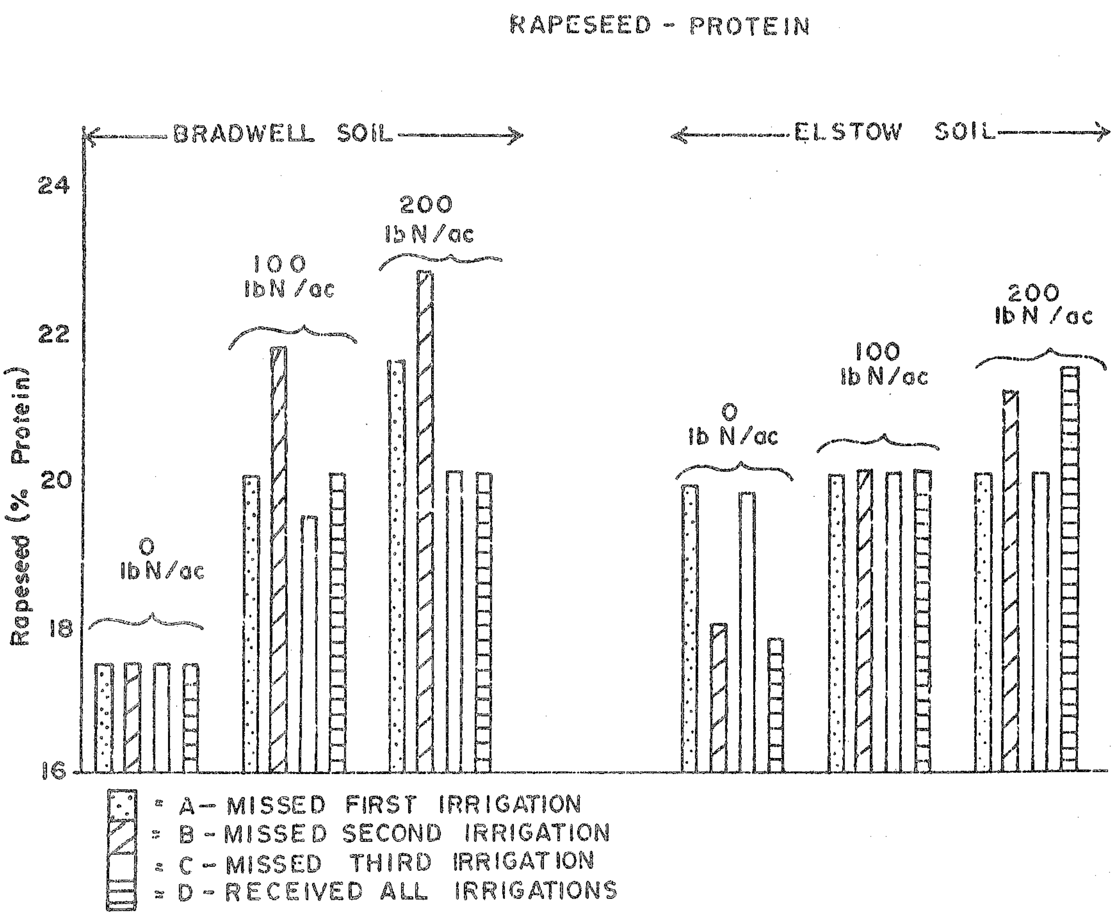


Fig 1.1.6 THE EFFECT OF DIFFERENT MOISTURE STRESSES ON THE PROTEIN CONTENT OF RAPESEED WITH DIFFERENT RATES OF NITROGEN

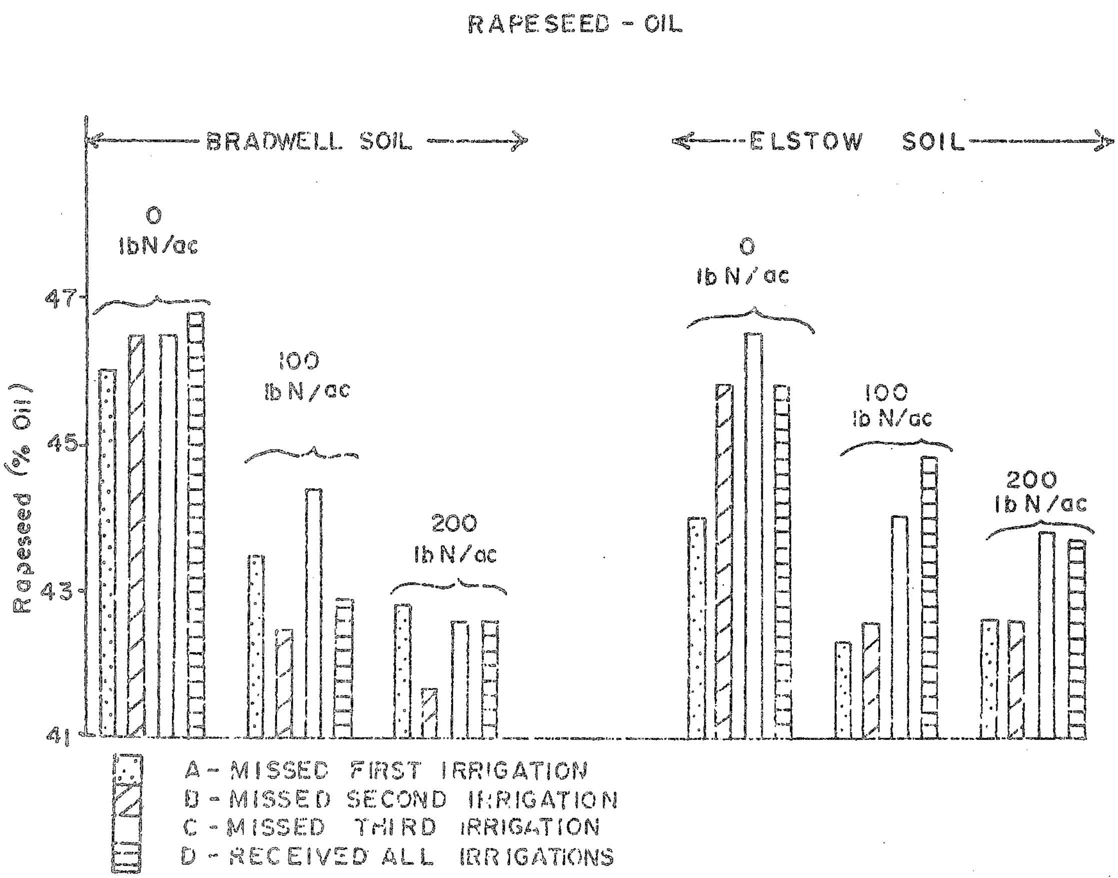


Fig. 1.1.7 THE EFFECT OF DIFFERENT MOISTURE STRESSES ON THE OIL CONTENT OF RAPESEED WITH DIFFERENT RATES OF NITROGEN

growing season (water C treatment) appeared to increase the protein content of soft wheat, particularly where either 100 or 200 lbs N/acre were added.

For rapeseed (Figure 1.1.6) on the Bradwell soil where no additional nitrogen was added irrigation scheduling had little effect on the protein content. Moisture stresses early in the growing season, combined with applications of either 100 or 200 lbs N/acre resulted in increases in the protein content of rapeseed. For the Elstow soil the protein data for rapeseed were highly variable and did not appear to be significantly affected by irrigation scheduling. The oil content of rapeseed (Figure 1.1.7) was reduced markedly by moisture stress early in the growing season on the Elstow soil.

CONCLUSIONS

Based on the research work conducted in 1974 and in previous years the following conclusions can be drawn:

1) Nitrogen is a major factor limiting the yields of cereals and oilseed crops grown under irrigated conditions. Where soil levels of available nitrogen are low it will be essential for producers to invest heavily in fertilizer nitrogen in order to achieve reasonable yield levels. However, where soil nitrogen levels are high (due possibly to previous cropping to potato) then reasonable yield levels can be obtained with little or no addition of fertilizer nitrogen.

2) Under conditions of high soil nitrogen the addition of high rates of fertilizer nitrogen could result in severe lodging of cereal crops and perhaps an actual yield reduction in soft wheat, and undesirably high protein content of soft wheat or malting barley and a

significant decline in the oil content of rapeseed. Soil testing will be essential to establish soil nitrogen levels and avoid disappointing crop yields or wasteful use of input dollars.

3) The proper timing and amount of application of irrigation water is particularly important in allowing the producer to capitalize on heavy investment in fertilizer nitrogen. The data from 1974 confirm the data obtained in 1973 which stress the importance of early irrigation to obtain optimum yields of irrigated crops.

1.2 Nutrient Requirements of Irrigated Potatoes

INTRODUCTION

Potatoes are a crop of major importance to the developing irrigation project in Saskatchewan. Soil fertility work on potatoes has been conducted in the past by the Department of Horticulture Science, University of Saskatchewan. Guidelines are available for nitrogen and phosphate use according to soil analysis.

However, there is little data available on the nitrogen uptake pattern of potatoes or on the utility of split nitrogen applications versus a single spring application. Therefore, a single experiment was designed to investigate:

1) The nitrogen uptake pattern of potatoes from applications made at various times throughout the growing season.

2) The response of potatoes to phosphorus, potassium and sulfur.

The experiment with irrigated potatoes was a joint project of the Department of Horticulture Science and the Department of Soil Science. Personnel from the Department of Horticulture Science carried out all field operations including planting, fertilizing, weeding and harvesting of the main field experiment and the laboratory determinations of specific gravity of the tubers.

EXPERIMENTAL METHODS

A single experiment was conducted on a Bradwell very fine sandy loam soil on the site of the PFRA demonstration farm at Outlook. Soil analysis taken prior to seeding (Table 1.2.1) showed a high to very high potassium level, a high phosphorus level and a high nitrogen

Table 1.2.1. Spring soil analysis for irrigated potatoes experiment.

Depth (inches)	Rep 1	Rep 2	Rep 3	Rep 4	Aver.
		NO_3^--N (lbs/acre)			
0-6	13	16	10	10	12
6-12	19	18	15	10	16
12-24	16(48)*	12(46)	18(43)	28(48)	19(47)
24-36	26	12	22	18	20
36-48	16	4	12	26	15
		P (lbs/acre)			
0-6	26	25	20	31	26
6-12	22	25	27	11	21
12-24	18	16	16	6	14
24-36	12	4	8	6	8
36-48	18	6	22	12	12
		K (lbs/acre)			
0-6	255	300	220	570	336
6-12	265	270	380	200	279
12-24	290	380	320	380	343
24-36	500	420	430	680	508
36-48	680	420	520	710	583

* Numbers in brackets are totals to 24 inches.

level according to current soil test benchmarks. However, for potatoes the current soil test benchmarks would indicate recommendations for nitrogen and phosphorus use and the potassium level was close to that for which a potassium fertilizer recommendation would be given.

The fertility treatments studied (Table 1.2.2) included a range of nitrogen rates up to 350 lbs/acre, a range of phosphorus rates up to 150 lbs P_2O_5/acre, a range of potassium rates up to 100 lbs K_2O/acre and a single rate of sulfur. The sources used were ammonium nitrate (34-0-0), monoammonium phosphate (11-55-0), potassium chloride (0-0-60) and ammonium sulfate (21-0-0-24).

Plot size was three rows at 3-feet spacing by 36 feet. Planting of the main experiment was done with a single row planter with double side banding equipment and harvesting was done mechanically. The experiment was replicated four times.

A special treatment was set aside within the main experiment for nitrogen uptake studies utilizing ^{15}N labelled ammonium nitrate. The ^{15}N treatments selected for study coincided with treatments 6, 15 and 16 of the main experiment. The specific details of the treatments utilized for the ^{15}N experiment are outlined in Table 1.2.3. For the split applications treatments were layed down to study the uptake of ^{15}N applied at various times of the growing season.

For the ^{15}N experiment labelled fertilizers were applied to a 3-foot length of the center row only of the main plot. The ^{15}N experiment was also replicated four times.

Harvesting for the ^{15}N experiment was conducted by manually removing tubers and plant tops. The plant tops were dried and ground for ^{15}N assay and the potato tubers were sampled by coring the tubers.

Table 1.2.2. Fertility treatments used for irrigated potatoes experiment.

Treatment Number	N	P_2O_5	K_2O	S
	lbs/acre			
1	0	100	0	0
2	50	100	0	0
3	75	100	0	0
4	100*	100	0	0
5	150*	100	0	0
6	225*	100	0	0
7	350*	100	0	0
8	225*	0	0	0
9	225*	50	0	0
10	225*	150	0	0
11	225*	100	50	0
12	225*	100	100	0
13	225*	100	0	50
14	225*	100	100	50
15	150	100	0	0
16	225**	100	0	0
17	(see Table 1.2.3)	100	0	0

* Split applications - 75 lb/acre applied with the seed, the remainder was applied about four weeks after seeding.

** Split application - three applications of 75 lb N/acre, one at seeding, one about three weeks after seeding, one about five weeks after seeding.

Table 1.2.3. Treatments used for nitrogen uptake portion of irrigated potatoes experiment.

Treatment Number	N Applied (lbs/acre)	Time of Application		
		At Seeding	3 Weeks After	5 Weeks After
		N lbs/acre		
1	150	150*		
2	225	75*	150	
3	225	75	150*	
4	225	75*	75	75
5	225	75	75*	75
6	225	75	75	75*

* These applications received ^{15}N labelled material. Non-labelled fertilizer was used for all other applications.

The material removed by cores was then dried and ground prior to analysis.

The calculation of % uptake of tagged nitrogen was performed using the average yield levels of the four replicates of the appropriate treatment from the main experiment. Yield levels were not obtained from the ^{15}N experiment per se. As yields of plant tops were not measured on the field experiment or ^{15}N experiment it was not possible to calculate % uptake of tagged N by plant tops.

RESULTS AND DISCUSSION

The yield data for the field experiment (Table 1.2.4) show no significant differences in yield between any of the treatments applied. Strong visual response to nitrogen was noted throughout the growing season. However, a severe frost prior to harvest resulted in significant damage to tubers and undoubtedly affected the yield potential.

The specific gravity data (Table 1.2.4) showed a slight reduction in specific gravity due to nitrogen fertilization. The applications of phosphorus, potassium or sulfur had no significant effect on the specific gravity of tubers.

The nitrogen uptake data (Table 1.2.5) showed a much higher percentage of nitrogen derived from fertilizer in both tubers and tops for the 150 lb N/acre rate applied at seeding, in comparison to the same rate of nitrogen applied three weeks after seeding. The 'A' values for both tubers and tops were also slightly lower for the application made at seeding time. However, the percent uptake of applied nitrogen by tubers was essentially the same for both times of application.

For the 75 lb N/acre rate the percent of nitrogen derived from

Table 1.2.4. The effect of fertilization on the yield and specific gravity of potatoes.

Treatment Number*	Tuber Yield (lbs/acre)	Tuber Specific Gravity
1	19598	1.09175
2	17991	1.09400
3	21696	1.09210
4	25179	1.08690
5	19911	1.08575
6	23750	1.08550
7	20938	1.08425
8	21250	1.08300
9	20625	1.08540
10	20938	1.08775
11	21696	1.08600
12	22723	1.08550
13	20357	1.08340
14	20491	1.08275
15	21116	1.08500
16	21205	1.09060
L.S.D.(.05)	N.S.	0.00495

*See Table 1.2.2 for explanation of treatments.

Table 1.2.5. The effect of time of application on the uptake of fertilizer nitrogen by irrigated potatoes as measured by ^{15}N assay techniques.

Treatment[1] Number	Tagged N Rate (lb/acre)	Tagged N Time	Rep	% NDFF[2] Tubers	% NDFF[2] Tops	'A' Value lbs/acre Tubers	'A' Value lbs/acre Tops	% Uptake[3] Tubers
1	150	Seeding	1	47.6	47.7	165	164	22.0
			2	43.1	47.2	198	168	19.9
			3	41.8	50.2	234	149	19.5
			4	41.6	45.2	209	182	18.9
			Mean ± S.D.	43.5±2.8	47.6±2.1	202±29	166±14	20.0±1.3
2	75	Seeding	1	24.0	18.0	238	342	24.1
			2	38.9	28.7	118	187	51.0
			3	24.0	24.3	238	234	23.9
			4	24.8	20.6	228	289	26.9
			Mean ± S.D.	27.9±7.3	22.9±4.7	206±58	263±67	31.5±13.1
3	150	3 weeks after	1	34.4	30.8	286	337	23.1
			2	31.5	29.9	326	352	21.0
			3	26.4	33.1	418	304	12.6
			4	28.5	28.9	376	369	16.8
			Mean ± S.D.	30.2±3.5	30.7±1.8	352±58	341±28	24.6±4.1
4	75	Seeding	1	23.1	22.6	250	257	27.1
			2	18.2	18.5	338	330	19.4
			3	26.7	29.2	206	182	27.1
			4	26.6	22.6	207	257	28.6
			Mean ± S.D.	23.7±4.0	23.2±4.4	250±62	257±60	25.6±4.2

Table 1.2.5. (continued).

Treatment Number[1]	Tagged N Rate (lb/acre)	Tagged N Time	Rep	% NDFF[2] Tubers	% NDFF[2] Tops	'A' Value lbs/acre Tubers	'A' Value lbs/acre Tops	% Uptake[3] Tubers
5	75	3 weeks after	1	23.0	23.5	251	244	24.3
			2	19.7	18.6	305	329	22.7
			3	24.9	23.6	226	244	25.1
			4	28.9	25.3	185	221	31.3
			Mean ± S.D.	24.1±3.8	22.8±2.9	242±50	260±48	25.9±3.8
6	75	5 weeks after	1	2.8	0.8	*	*	2.5
			2	20.2	20.8	296	286	19.9
			3	1.0	0.5	*	*	0.9
			4	0.5	0.5	*	*	0.6

[1] For complete treatment information see Table 1.2.3.

[2] % NDFF = % of nitrogen derived from tagged fertilizer nitrogen.

[3] % uptake of tagged fertilizer nitrogen.

* Negligible uptake of tagged nitrogen.

fertilizer, 'A' values and percentage uptake in tubers were essentially the same for applications made at seeding time or three weeks after seeding. For the treatment in which the 75 lb N/acre rate was applied five weeks after seeding, in three of the four replicates there was essentially no uptake of tagged fertilizer nitrogen. Because of the erratic nature of the data for this treatment it is not possible to draw any firm conclusions about the uptake of fertilizer nitrogen by potatoes for applications made in mid-growing season.

This experiment has provided useful preliminary data on which to build future programs but it is impossible to draw firm conclusions based on a single experiment.

1.3 Residual Nitrogen at the End of the Growing Season

To determine the possibility of residual response to nitrogen in subsequent years and to determine the potential for downward movement of nitrate-nitrogen into the groundwater, a detailed fall soil sampling program was conducted on the two major irrigation experiments on Bradwell and Elstow soil types. Samples were taken from all irrigation scheduling treatments and from the 0 and 200 lb N/acre rate for all three crops. Two soil cores (2 inch diameter) were removed from each replicate of the above treatments for each crop. Samples of the eight cores from each nitrogen and water treatment for each crop were composited, air-dried and analyzed for nitrate-nitrogen content. The results are presented in Table 1.3.1.

For the Bradwell soil there was evidence of significant levels of residual nitrogen in almost all cases. For the water A treatment the residual nitrogen existed mainly in the second and third feet of the soil profile. For the water D treatment there was evidence of leaching of nitrogen beyond the four foot depth. For soft wheat, significant quantities of nitrogen existed in the three and four feet depths, while for both rapeseed and barley there was little evidence of the residual nitrogen existing within the measured profile. In the water B and water C treatment most of the residual nitrogen existed in the second and third feet of the soil profile.

For the Elstow soil there was also evidence of substantial quantities of residual nitrogen for most crop and water treatments. For the water A treatment the majority of the residual nitrogen existed in the second and third foot depths of the soil profile. For the water B and water D treatments there was evidence of leaching below

Table 1.3.1. Residual nitrate nitrogen levels from various rates of nitrogen application and various irrigation treatments.

Depth (inches)	Water A N rate (lb/acre) 0	Water A 200	Water B N rate (lb/acre) 0	Water B 200	Water C 0	Water C 200	Water D N rate (lb/acre) 0	Water D 200
	lbs NO_3-N/acre							
ELSTOW : L								
Barley								
0-6	6	22	13	19	13	17	7	14
6-12	6	7	5	28	10	35	4	10
12-24	10	40	10	58	28	32	8	28
24-36	14	30	12	64	36	24	12	26
36-48	24	18	10	30	22	38	18	30
Soft Wheat								
0-6	13	25	10	25	10	23	10	12
6-12	5	28	5	21	4	26	4	10
12-24	10	92	10	48	8	40	8	32
24-36	22	18	12	26	8	34	10	18
36-48	18	20	16	16	12	22	22	18
Rapeseed								
0-6	6	16	11	15	5	23	8	20
6-12	6	35	5	10	2	41	5	33
12-24	12	36	12	28	6	92	10	38
24-36	50	34	28	42	16	40	14	30
36-48	30	30	16	32	30	48	20	34
BRADWELL : VL								
Barley								
0-6	8	30	3	22	6	15	13	11
6-12	8	19	2	41	5	7	4	13
12-24	16	66	6	14	4	24	10	14
24-36	20	36	8	8	4	16	6	8
36-48	16	16	8	12	6	8	6	12
Soft Wheat								
0-6	6	20	6	19	13	23	12	7
6-12	5	14	4	14	5	15	11	8
12-24	8	18	10	26	10	20	14	24
24-36	32	88	10	58	34	22	8	46
36-48	16	28	40	18	22	12	8	82
Rapeseed								
0-6	14	25	9	15	7	20	8	18
6-12	4	8	4	21	4	17	6	12
12-24	8	26	8	62	8	44	12	18
24-36	6	54	16	24	18	50	22	16
36-48	8	24	14	16	18	18	28	20

four feet for barley and rapeseed but not under soft wheat. For the water C treatment significant quantities of residual nitrogen existed at the two foot depth for rapeseed and soft wheat, and at the one foot depth for barley.

In general, the data on residual levels of nitrogen after the crop season provide more evidence of leaching below the four foot depth than was obtained in previous studies conducted through the years 1971 to 1973.

2. CROP UTILIZATION AND FATE OF FERTILIZER NITROGEN IN SOIL

INTRODUCTION

In recent years, numerous research projects have been conducted by various agencies in Western Canada evaluating crop responses to different rates, carriers, methods, and times of applying fertilizer nitrogen. Results of these experiments have conclusively demonstrated that yields of most stubble seeded crops and a small percentage of fallow seeded crops are limited by the amounts of available nitrogen present in the soil. Hence good responses to applied fertilizer nitrogen are attainable. However, few definite statements can be made regarding the relative efficiency of different nitrogen carriers, methods, and times of application. Experimental results relating to these factors have been, in many cases, inconsistent and often contradictory. Such observations tend to indicate that the relative efficiencies of different fertilizer applications are determined not only by specific soil properties, but also by the type of crop and by environmental conditions present during a given growing season. For example, conclusions drawn in a review of available research data comparing the responses of annual crops to urea and ammonium nitrate stated that over a number of years and over a number of different soil types, average yields were similar from both carriers when broadcast or when broadcast and incorporated (McGill, 1973). Included in these averages, however, were results from certain trials in which fairly large differences between the carriers were apparent. Similarly, with regard to the question of nitrogen placement, while it is often thought that side banding is a more effective application technique than broadcasting, and that seed placement is effective only at low rates, results from some trials in some years are not in agreement (McGill *et al.*, 1973; Paul *et al.*, 1972).

At present, relatively little data is available from the Canadian prairies comparing spring and fall nitrogen application. Results from a number of trials conducted in Manitoba between 1967 and 1974 indicate that fall application is, at best, equal to spring application for cereal crops (Partridge and Ridley, 1974). Differences have been noted that can be related to geographic location in that fall applications on the average have been less effective than corresponding spring applications in the Manitoba lowlands, while on the Manitoba uplands, average responses from spring and fall applications have been similar. Results from Alberta in 1974 indicated that, in three out of four trials, yields were consistently larger from spring-applied nitrogen than from fall-applied nitrogen, and in the fourth trial, differences between application times were small (Malhi and Nyborg, 1974). Differences between fall and spring applications varied considerably with different nitrogen sources.

In the fall of 1973, a research program was initiated to determine, under Saskatchewan conditions, whether:

a) differences do exist between i) organic urea nitrogen and inorganic ammonium and nitrate-nitrogen, ii) broadcast, side banded and seed placed nitrogen fertilizers, and iii) fall and spring fertilizer applications;

b) if differences do exist, whether these differences could be related to specific soil and climatic conditions such that reasonable recommendations could be made as to soils and areas in Saskatchewan where certain nitrogen fertilization practices should be followed.

This report presents results obtained from field experiments conducted during the initial year of the project, 1973-74.

2.1 Response of Annual Crops to Different Sources, Times, and Methods of Applying Nitrogen Fertilizer

EXPERIMENTAL METHODS

In the fall of 1973, six sites were selected for the establishment of field trials. Two sites were on Dark Brown soils (Elstow and Weyburn), three sites were on Black soils (Hoey, Naicam, Yorkton), and one site was on a Grey Wooded soil (Waitville). The Weyburn, Yorkton and Waitville sites represent three soils developed on similar glacial till material, occurring in different soil zones. The Elstow, Hoey and Naicam soil sites represent, respectively, silty lacustrine, modified silty clay lacustrine, and resorted glacial till parent materials. Results of analyses of soil samples taken at the time of plot establishment (fall, 1973) are presented in Table 2.1.1. Nitrate-nitrogen contents of the soils at all but one site were in the low and very low category. The Yorkton soil site, which had already grown four crops, contained considerable quantities of NO_3-N in the second foot, the presence of which was verified by sampling at spring seeding time. All but the Grey Wooded soil were low in available P.

At each site, small plots of randomized complete block design were established containing fifteen treatments replicated six times. Treatments included (Table 2.1.2) a check, two nitrogen carriers (urea and ammonium-nitrate) applied at 2 rates (50 and 100 lbs N/acre) in the fall and at 5 rates (25, 50, 75, 100 and 150 lbs N/acre) in the spring. One site, the Naicam soil site, was chosen to be the "central site", where beyond the 15 basic treatments, additional treatments

Table 2.1.1 Characteristics of soils from sites selected for 1974 nitrogen fertilizer studies[1].

Soil Type/ Texture	Depth (in.)	O.M. %	$CaCO_3$ %	Nutrient Content (lb/acre) NO_3-N	P	K	pH	Cond. mmho/cm
Elstow:SiCl	0- 6	2.7	3.07	6	5 VL[2]	455	7.3	0.4
Dark Brown	6-12	1.9	6.52	1	3	275	7.5	0.4
	12-24			4	4	680	7.8	0.4
				11 VL				
Weyburn:l	0- 6	4.4	0.38	10	15 L	865	7.2	0.6
Dark Brown	6-12	2.5	0.38	5	7	450	7.1	0.6
	12-24			6	5	760	7.1	1.7
				21 L				
Hoey:SiCl	0- 6	7.7	0.23	9	11 L	430	6.5	0.2
Thick Black	6-12	3.8	0.38	3	6	265	6.7	0.2
	12-24			6	8	520	7.3	0.6
				18 L				
Naicam:l	0- 6	7.0	1.05	12	14 L	290	7.4	0.4
Thick Black	6-12	4.2	0.43	5	6	215	7.5	0.3
	12-24			4	8	630	7.8	0.3
				21 L				
Yorkton:l	0- 6	6.2	1.69	13	7 VL	235	7.5	1.3
Thick Black	6-12	4.5	1.15	4	4	180	7.5	2.3
	12-24			46	4	390	7.7	2.6
				63 VH				
Waitville:l	0- 6	3.6	0.23	1	23 H	275	7.0	0.2
	6-12	1.6	0.08	3	11	275	6.7	0.2
	12-24			2	20	530	7.1	0.6
				6 VL				

[1]Results of samples taken in fall, 1973.

[2]Nutrient availability categories as designated by the Saskatchewan Soil Testing Laboratory.
VL - very low; L - low; M - medium; H - high; VH - very high.

Table 2.1.2 Treatments[1] included in 1974 nitrogen fertilizer trials.

Nitrogen Application (lb/acre)	Nitrogen Sources	Time of Application
0		
25	A.N., U.	S
50	A.N., U.	S, F
75	A.N., U.	S
100	A.N., U.	S, F
150	A.N., U.	S

A.N. - Ammonium Nitrate

U. - Urea

S. - Spring

F - Fall

[1] At the Naicam soil site, all spring treatments were applied in broadcast, sideband, and seed-placed placement. At the remaining sites, treatments were broadcast only.

involving side banding and seed placement of both carriers at the five spring application rates were included. Here, also three separate plots were established adjacent to each other to allow for investigation into the relative responses of three different annual crops.

In the late fall of 1973, the nitrogen was applied to the fall treatments at all sites (Table 2.1.3). At all locations except the Hoey soil site, nitrogen was broadcast during snowfall or after one or more inches of snow covered the ground. Therefore, at all of the sites the fertilizer was not incorporated until normal spring tillage operations were performed. At seeding time, all plots were worked, seeded, and broadcast nitrogen was applied after seeding. Bonanza barley was seeded at all sites with the additional two plots at the Naicam site being seeded to Neepawa wheat and Midas rapeseed. All crops except rapeseed received a blanket application of 40 lb P_2O_5/acre seed placed as monoammonium phosphate (11-55-0); rapeseed similarly received phosphate at a rate of 30 lb P_2O_5/acre. All sites were seeded abnormally late (Table 2.1.3) due to the extremely wet and cool spring conditions.

A pre-seeding application of triallate (Avadex-BW) for wild oat control was applied and incorporated on all barley plots, while the rapeseed plot received a pre-seeding application of Treflan. Wild oats were successfully controlled at all sites. As required, the barley plots received post-emergent spray applications in the form of Buctril-M, or MCPA and TCA. The wheat and rapeseed plots on the Naicam soil were respectively sprayed with Buctril-M, and TOK/RM mixed with TCA. Weed control at most plots was fairly good. Only slight problems were encountered with green foxtail, since this weed is hard to

Table 2.1.3 Dates of fall fertilization, spring seeding and harvest, and amounts of seasonal precipitation for 1974 nitrogen fertilizer trials.

Site	Fall Fertilization	Seeding	Harvest	Seasonal Precip. (in)
Elstow	Nov. 1/73*	May 17/74	Aug. 20/74	7.3
Bradwell	Nov. 1/73*	May 31/74	Aug. 19/74	7.4
Hoey	Oct. 30/73	June 7/74	Sept. 5/74	13.9
Naicam				
- barley	Nov. 1/73*	June 6/74	Sept. 6/74	
- wheat	Nov. 1/73	June 4-5/74	Sept. 7/74	
- rapeseed	Nov. 1/73	June 4/74	Sept. 9/74	
Yorkton	Oct. 31/73*	June 12/74	Sept. 17/74	8.7
Waitville	Oct. 31/73*	June 9/74	Sept. 18/74	9.2

*Fall fertilizer applied during or after snowfall.

control in barley with the rate of TCA allowable.

Between seeding and harvest, most plots received reasonable amounts of rainfall (Table 2.1.3). The Hoey site, however, received much higher than average rainfall, while the Naicam site received a relatively small amount. As a result of extremely late seeding, crops on both the Yorkton and Waitville plots were affected by early frosts. The barley on the Waitville site, in particular, was far from mature when the killing frost occurred and as a result, most heads had not completely filled.

Harvest samples were taken from all plots. These samples were air-dried, weighed, threshed, cleaned and yields calculated. Grain and straw samples were retained from all treatments at all sites (replicates bulked) and ground for protein and nitrogen analysis.

Included in each of the plots at all locations was a small subplot in which ^{15}N enriched fertilizer materials were utilized to allow for detailed uptake and balance measurements. The subplot consisted of 24 eighteen-inch long, six-inch diameter cylinders driven into the ground. These cylinders represented six treatments replicated four times. Treatments included the following all applied at a rate of 50 lbs N/acre:

1) Urea-^{15}N fall applied
2) $^{15}NH_4NO_3$ fall applied
3) $NH_4{}^{15}NO_3$ fall applied
4) Urea-^{15}N spring applied
5) $^{15}NH_4NO_3$ spring applied
6) $NH_4{}^{15}NO_3$ spring applied

Each of the fertilizers were applied at the same time as nitrogen was applied on the large plots. The cylinders were "hand worked" and seeded in spring. At harvest, all aboveground plant material was taken from each cylinder, dried, weighed, threshed, ground and retained for total N and ^{15}N measurements. The cylinders were dug up (frozen until processed) and the soil was removed in six-inch increments, weighed, dried and subsampled in preparation for total nitrogen and ^{15}N analyses. Results from these subplots are presented in a subsequent section of this report.

RESULTS AND DISCUSSION

Yield results for various plots are given in Tables 2.1.4 to 2.1.9. Corresponding nitrogen uptake data are presented in Table 2.1.10. Yield results in Table 2.1.6 for the Grey Wooded Waitville soil site are given in terms of cwt/acre total dry matter yield, as well as bu/acre grain yield, since the crop yields were severely affected by frost and, hence, total weight is probably a better indication of response.

Response to Applied Nitrogen

Good responses to applied nitrogen were obtained on the two Dark Brown soil sites where maximum barley yields of slightly greater than 50 bu/acre were obtained at both locations (Table 2.1.4). The relatively larger yield increases obtained on the Elstow site probably are due to the initial lower NO_3-N content of the soil (which may in part reflect its nitrogen supplying power with the organic matter content also being very low), since rainfall at the two sites was similar.

Data presented in Table 2.1.10 indicate good utilization of applied fertilizer nitrogen on both Dark Brown soils since the protein content

Table 2.1.4 Effect of spring and fall broadcast nitrogen on yields of barley on two Dark Brown soils.

Nitrogen Application (lb/acre)	Yield[1]							
	Ammonium Nitrate				Urea			
	Spring		Fall		Spring		Fall	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
A) ELSTOW SOIL								
0	20.5	7.8						
25	31.5	12.8			32.1	12.4		
50	42.7	19.0	43.3	20.8	43.6	18.7	39.4	19.2
75	44.9	20.7			42.6	17.2		
100	44.9	19.6	52.1	30.8	52.8	21.3	49.7	25.0
150	44.9	19.3			51.6	20.7		
B) WEYBURN SOIL								
0	37.9	15.1						
25	44.1	17.5			50.6	19.8		
50	51.6	21.3	55.0	26.6	47.2	26.5	45.9	21.7
75	55.8	27.6			48.8	23.0		
100	51.5	25.2	51.7	30.1	52.2	25.0	53.0	30.1
150	48.1	30.9			53.3	30.4		

[1]Grain yield in terms of bu/acre and straw yield in terms of cwt/acre.

Table 2.1.5 Effect of spring and fall broadcast nitrogen on yield of barley on two Black soils.

Nitrogen Application (lb/acre)	Yield[1]							
	Ammonium Nitrate				Urea			
	Spring		Fall		Spring		Fall	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
C) HOEY SOIL								
0	42.3	20.2						
25	61.5	28.1			54.9	25.3		
50	72.6	39.9	66.0	43.8	73.0	33.9	65.0	40.2
75	79.2	43.7			75.2	39.3		
100	81.7	39.5	78.8	52.0	79.6	43.7	73.0	47.9
150	86.0	51.8			84.4	47.1		
D) YORKTON SOIL								
0	33.3	13.6						
25	37.7	14.4			37.5	14.3		
50	35.1	14.9	36.0	25.4	39.7	18.9	38.3	19.4
75	40.5	17.9			39.1	15.3		
100	39.2	17.8	36.2	25.8	38.3	17.9	39.1	28.2
150	41.8	17.8			41.0	16.7		

[1] Grain yields in terms of bu/acre and straw yields in terms of cwt/acre.

Table 2.1.6 Effect of spring and fall applied nitrogen on the grain and total dry matter yields of barley on Waitville Grey Wooded soil.

Nitrogen Application (lb/acre)	Ammonium Nitrate		Yield	Urea	
	Spring	Fall		Spring	Fall
A) GRAIN - bu/acre					
0			16.1		
25	21.0			21.8	
50	25.7	23.0		23.8	21.5
75	30.7			25.8	
100	27.2	20.6		29.8	19.7
150	25.7			27.4	
B) TOTAL DRY MATTER - cwt/acre					
0			22.5		
25	30.9			29.6	
50	40.4	39.4		34.9	34.5
75	43.9			41.4	
100	42.4	39.7		44.3	38.4
150	41.1			44.4	

Table 2.1.7 The effect of different times and methods of nitrogen application on the yield of barley on Naicam soil.

Nitrogen Application (lb/acre)	Yield[1]							
	Broadcast		Sideband		Seed Placed		Fall	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
A) AMMONIUM NITRATE								
0	22.6	8.9						
25	30.6	10.9	28.8	11.5	30.0	12.7		
50	33.1	10.9	34.0	12.5	32.3	12.3	26.1	12.0
75	36.3	12.9	39.4	15.4	34.6	14.6		
100	35.7	12.6	38.9	14.8	32.4	17.7	29.8	15.0
150	32.1	11.7	35.1	13.7	33.1	14.8		
B) UREA								
25	34.5	12.2	31.1	12.1	30.1	13.0		
50	33.8	12.0	34.2	13.1	32.2	13.7	28.2	12.3
75	38.7	12.8	38.4	12.5	31.0	15.6		
100	36.1	12.0	37.1	13.7	28.2	13.7	27.6	12.7
150	37.2	13.2	37.0	14.8	18.6	11.6		

[1]Grain yield based on bu/acre and straw yield on cwt/acre.

Table 2.1.8 The effect of different times and methods on nitrogen application on the yield of wheat on Naicam soil.

Nitrogen Application (lb/acre)	Yield[1]							
	Broadcast		Sideband		Seed Placed		Fall	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
A) AMMONIUM NITRATE								
0	16.0	8.9						
25	17.3	9.6	19.5	10.6	19.5	11.1		
50	20.3	11.0	18.3	10.3	23.3	13.4	20.6	11.5
75	21.8	13.3	23.6	13.2	21.5	15.4		
100	20.1	11.4	23.5	14.2	23.2	13.1	18.1	12.2
150	23.2	13.5	24.7	13.9	22.8	13.9		
B) UREA								
25	18.6	9.1	19.5	10.7	19.9	11.2		
50	22.0	11.4	20.4	11.4	13.8	7.3	20.0	11.3
75	20.4	11.2	22.3	12.4	5.3	3.2		
100	24.8	14.2	24.5	13.4	7.4	5.8	20.6	13.6
150	21.3	12.1	25.0	15.5	4.4	6.2		

[1]Grain yields in terms of bu/acre and straw yields in cwt/acre.

Table 2.1.9 The effect of different times and methods of nitrogen application on the yield of rapeseed on Naicam soil.

Nitrogen Application (lb/acre)	Yield[1]							
	Broadcast		Sideband		Seed Placed		Fall	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
A) AMMONIUM NITRATE								
0	6.7	10.8						
25	8.5	13.0	14.5	18.1	10.4	16.3		
50	13.7	17.2	15.9	19.7	9.1	20.9	15.1	16.9
75	16.8	20.4	16.9	21.0	12.0	20.7		
100	17.3	24.6	16.8	24.8	8.9	20.5	16.6	20.4
150	18.2	27.3	18.1	24.7	4.9	10.2		
B) UREA								
25	11.0	15.0	12.4	19.0	6.0	11.0		
50	14.6	18.6	15.1	20.0	5.8	9.9	11.8	15.7
75	15.5	20.8	17.8	19.9	4.7	11.3		
100	18.7	24.4	16.3	23.2	5.5	6.7	15.4	19.7
150	14.9	24.4	16.9	22.6	0	0		

[1] Grain yields are in bu/acre and straw yields in cwt/acre.

Table 2.1.10 Nitrogen and protein content[1] and total nitrogen uptake of crops from 1974 nitrogen study plots.

Treatment Nitrogen Applied/ Time	Source: Ammonium Nitrate					Source: Urea				
	Grain % Protein	Straw % N	Nitrogen Uptake (lb/acre)			Grain % Protein	Straw % N	Nitrogen Uptake (lb/acre)		
			Grain	Straw	Total			Grain	Straw	Total
A) ELSTOW SOIL SITE - Barley										
0	8.6	0.39	13.7	3.1	16.8	8.6	0.39	13.7	3.1	16.8
25-spring	9.4	0.43	22.7	5.5	28.2	9.6	0.55	23.7	6.8	30.5
50 "	9.6	0.46	31.6	8.7	40.3	10.4	0.58	34.9	10.8	45.7
75 "	10.4	0.74	36.1	15.3	51.4	11.3	0.61	37.1	10.5	47.6
100 "	11.4	0.63	39.4	12.4	51.8	11.7	0.86	47.6	18.3	65.9
150 "	12.6	0.81	47.2	15.6	62.8	12.6	0.93	49.7	19.2	68.9
50-fall	8.8	0.51	29.2	10.6	39.8	8.5	0.40	25.6	7.7	33.3
100 "	10.8	0.81	43.4	25.0	68.4	10.1	0.63	38.5	15.8	54.3
B) WEYBURN SOIL SITE - Barley										
0	9.83	0.46	28.7	7.0	35.7	9.83	0.46	28.7	7.0	35.7
25-spring	10.38	0.46	35.2	8.0	43.2	10.68	0.59	41.5	11.7	53.2
50 "	11.79	0.58	46.7	12.4	59.1	11.25	0.57	40.8	15.1	55.9
75 "	12.35	0.64	52.9	17.6	70.5	12.35	0.60	46.3	13.8	60.1
100 "	13.05	0.83	51.6	20.9	72.5	13.05	0.74	52.3	18.5	70.8
150 "	13.51	1.06	49.9	32.8	82.7	12.95	0.94	53.0	28.6	81.6
50-fall	11.94	0.74	50.0	19.7	69.7	9.93	0.65	34.0	14.1	49.1
100 "	13.46	0.88	53.4	26.5	79.9	10.68	0.74	43.5	22.3	65.8

[1] Straw % N based on oven dry basis; grain % protein based on % N @ 13.5% moisture x 6.25 (barley and rape) or x 5.7 (wheat).

Table 2.1.10 Con't.

Treatment Nitrogen Applied/ Time	Source: Ammonium Nitrate					Source: Urea				
	Grain % Protein	Straw % N	Nitrogen Uptake (lb/acre)			Grain % Protein	Straw % N	Nitrogen Uptake (lb/acre)		
			Grain	Straw	Total			Grain	Straw	Total
C) HOEY SOIL SITE - Barley										
0	9.2	0.53	29.9	11.0	40.9	9.2	0.53	29.9	11.0	40.9
25-spring	9.8	0.48	46.2	13.5	59.7	8.5	0.53	35.9	13.4	49.3
50 "	9.7	0.60	54.0	25.5	79.5	10.2	0.52	57.4	17.6	75.0
75 "	10.9	0.59	66.2	25.8	92.0	10.3	0.64	59.6	25.2	84.8
100 "	10.8	0.71	68.0	28.0	96.0	11.0	0.68	67.2	29.7	96.9
150 "	11.4	1.06	75.2	54.9	130.1	11.6	0.97	75.1	45.7	120.8
50-fall	9.3	0.52	47.0	22.8	69.8	8.2	0.60	41.0	24.1	65.1
100 "	10.8	0.71	65.3	36.9	102.2	9.2	0.48	51.7	23.0	74.7
D) YORKTON SOIL SITE - Barley										
0	10.7	1.06	27.4	14.4	41.8	10.7	1.06	27.4	14.4	41.8
25-spring	10.6	1.11	30.8	16.0	46.8	10.7	1.02	30.8	14.6	45.4
50 "	10.7	1.21	28.8	18.0	46.8	11.0	1.15	33.7	21.7	55.4
75 "	11.8	1.23	36.8	22.0	58.8	11.9	1.20	35.9	17.2	53.1
100 "	11.1	1.44	33.5	25.6	59.1	11.9	1.48	35.0	26.6	61.6
150 "	11.4	1.33	36.7	23.7	60.4	11.7	1.34	26.8	22.4	59.2
50-fall	11.2	1.25	31.0	31.7	62.7	11.6	1.11	32.1	21.5	53.6
100 "	11.8	1.57	32.9	40.5	73.4	11.3	1.23	34.1	34.7	68.8

Table 2.1.10 Con't

Treatment Nitrogen Applied/ Time	Source: Ammonium Nitrate					Source: Urea				
	Grain % Protein	Straw % N	Nitrogen Uptake (lb/acre)			Grain % Protein	Straw % N	Nitrogen Uptake (lb/acre)		
			Grain	Straw	Total			Grain	Straw	Total
E) WAITVILLE SOIL SITE - Barley										
0	7.9	0.88	9.8	13.1	22.9	7.9	0.88	9.8	13.1	22.9
25-spring	8.2	0.87	13.2	18.1	31.3	8.8	0.88	14.8	16.8	31.6
50 "	9.3	1.07	18.3	30.1	48.4	9.7	1.13	17.7	26.5	44.2
75 "	10.0	1.09	23.5	31.8	55.3	9.8	1.09	19.5	31.7	51.2
100 "	10.2	1.48	21.3	43.4	64.7	10.4	1.58	23.4	47.4	71.3
150 "	11.0	1.53	21.8	44.0	65.8	11.0	1.53	23.2	47.8	71.0
50-fall	9.4	1.11	16.6	31.4	48.0	8.2	0.99	23.5	24.0	37.5
100 "	9.9	1.37	15.6	40.8	56.4	9.6	1.30	14.6	37.6	52.2
F) NAICAM SOIL SITE - Barley										
0	10.3	0.93	17.3	8.2	25.2	10.3	0.93	17.3	8.2	25.2
25-spring	12.2	1.10	28.7	12.0	40.7	11.2	0.92	29.6	11.3	40.9
50 (Broad-cast)	11.7	1.16	29.8	12.6	42.4	11.8	1.08	30.6	13.0	43.6
75 "	13.0	1.15	36.1	14.8	50.9	12.3	1.13	36.6	14.4	51.0
100 "	12.9	1.20	35.2	15.1	50.3	12.8	1.00	35.5	12.0	47.5
150 "	12.9	1.30	31.7	15.2	46.9	12.9	1.36	36.7	18.0	54.7
25-spring	12.0	0.86	26.5	9.9	36.4	11.1	0.80	26.5	9.7	36.2
50 (Side banded)	12.1	0.87	31.6	10.9	42.5	11.1	1.06	29.1	13.9	43.0
75 "	12.2	1.04	36.8	16.0	52.8	12.4	1.16	36.6	14.6	51.2
100 "	12.3	1.36	36.7	20.2	56.9	13.0	1.10	37.0	15.1	52.1
150 "	12.8	1.32	34.4	18.1	52.5	12.9	1.43	36.5	21.1	57.6

Table 2.1.10 Con't

Treatment Nitrogen Applied/ Time	Source: Ammonium Nitrate					Source: Urea				
	Grain % Protein	Straw % N	Nitrogen Uptake (lb/acre)			Grain % Protein	Straw % N	Nitrogen Uptake (lb/acre)		
			Grain	Straw	Total			Grain	Straw	Total
25-spring	11.2	1.08	25.9	13.7	39.6	11.2	1.23	25.9	16.0	41.9
50 (Seed Placed)	11.3	1.12	28.0	13.8	41.8	11.6	1.54	28.8	21.1	49.9
75 "	12.2	1.39	32.4	20.3	52.7	11.9	1.45	28.4	22.6	51.0
100 "	12.9	1.37	32.0	24.3	56.3	12.3	1.51	26.6	20.8	47.4
150 "	12.2	1.74	31.0	25.7	56.7	12.1	1.78	17.3	20.6	37.9
50-fall	11.8	1.30	23.6	16.1	39.7	11.5	1.21	25.0	14.8	39.8
100 "	13.3	1.30	30.5	19.5	50.0	12.5	1.38	26.4	17.5	43.9
G) NAICAM SOIL SITE - Wheat										
0	12.67	0.54	21.7	4.9	26.6	12.67	0.54	21.7	4.9	26.6
25-spring	14.0	0.73	25.5	7.0	32.5	14.3	0.71	28.0	6.5	34.5
50 (Broad-cast)	15.4	0.87	32.9	9.6	42.5	14.4	0.76	33.4	8.7	42.1
75 "	15.0	0.86	34.5	11.4	45.9	14.3	0.73	30.7	8.2	38.9
100 "	15.0	0.85	31.8	9.7	41.5	14.2	0.91	37.0	12.9	49.9
150 "	15.2	0.88	37.1	11.8	48.9	13.7	0.87	30.6	10.5	41.1
25-spring	13.7	0.71	28.0	7.6	35.6	13.9	0.77	28.5	8.2	36.7
50 (Side-banded)	14.8	0.85	28.5	8.8	37.3	14.3	0.78	30.6	8.9	39.5
75 "	14.0	0.87	34.9	11.5	46.4	14.0	0.88	32.9	10.9	43.8
100 "	14.1	0.95	34.8	13.5	48.3	14.6	0.92	37.7	12.3	50.0
150 "	14.4	0.87	37.5	12.1	49.6	14.9	1.01	39.1	15.7	54.8

Table 2.1.10 Con't

Treatment Nitrogen Applied/ Time	Source: Ammonium Nitrate					Source: Urea				
	Grain % Protein	Straw % N	Nitrogen Uptake (lb/acre)			Grain % Protein	Straw % N	Nitrogen Uptake (lb/acre)		
			Grain	Straw	Total			Grain	Straw	Total
25-spring	12.7	0.64	26.1	7.1	33.2	13.6	0.81	28.5	12.6	41.1
50 (Seed placed)	14.0	0.94	34.4	12.6	47.0	13.3	0.85	19.3	6.2	25.5
75 "	14.2	0.86	32.2	13.2	46.4	13.6	0.92	17.6	2.9	10.5
100 "	13.9	0.91	34.1	12.0	46.1	13.4	1.07	10.4	6.2	16.6
150 "	13.9	1.07	33.3	14.8	48.1	12.7	1.24	5.9	7.7	13.6
50-fall	13.9	0.74	30.0	8.5	38.5	12.7	0.66	26.6	7.4	34.0
100 "	14.5	0.92	27.6	11.2	38.8	14.0	0.83	30.3	11.3	41.6

Table 2.1.10 Con't

Treatment Nitrogen Applied/ Time	Source: Ammonium Nitrate						Source: Urea					
	Grain % Protein	Straw % N	Nitrogen Uptake (lb/acre)			Grain Oil %	Grain % Protein	Straw % N	Nitrogen Uptake (lb/acre)			Grain Oil %
			Grain	Straw	Total				Grain	Straw	Total	
H) NAICAM SOIL SITE - Rapeseed												
0	19.5	0.79	11.0	8.7	19.7	44.9	19.5	0.79	11.0	8.7	19.7	44.9
25-spring	19.9	0.85	13.6	11.0	24.6	44.7	18.8	0.88	16.6	12.7	29.3	45.8
50 (Broad-cast)	20.9	1.00	22.9	17.2	40.1	44.5	20.2	0.95	23.5	17.7	41.2	44.0
75 "	22.0	1.23	39.5	25.1	64.6	43.8	21.3	1.10	26.4	22.9	49.3	44.5
100 "	22.3	1.29	31.0	31.8	62.8	42.6	22.2	1.30	33.2	31.7	64.9	43.8
150 "	22.2	1.62	32.4	44.2	76.6	42.3	22.4	1.51	26.8	36.8	63.6	43.6
25-spring	19.5	0.82	22.6	14.9	37.5	45.0	19.7	0.88	19.5	16.7	36.2	45.1
50 (Side-banded)	20.5	1.04	26.1	20.5	46.6	43.8	20.4	1.02	24.7	20.4	45.1	44.8
75 "	20.9	1.10	28.4	23.1	51.5	43.4	21.7	1.02	30.9	20.3	51.2	44.5
100 "	21.7	1.32	39.2	32.7	71.9	42.5	22.0	1.16	28.6	26.9	55.5	44.0
150 "	22.3	1.50	32.4	37.1	69.5	43.4	22.7	1.30	30.6	29.4	60.0	43.4
25-spring	20.0	1.03	16.7	16.8	33.5	46.8	20.6	0.86	9.9	9.5	19.4	44.2
50 (Seed Placed)	20.4	1.10	14.9	23.0	37.9	45.3	20.5	1.20	9.4	11.9	21.3	45.6
75 "	21.2	1.34	20.3	28.7	49.0	43.3	21.4	1.44	8.1	16.3	24.4	44.3
100 "	22.0	1.74	15.7	35.7	51.4	42.5	21.8	1.56	6.1	10.5	16.6	43.6
150 "	21.8	1.72	8.5	17.6	26.1	42.9	--	--	--	--	--	--
50-fall	21.3	1.03	25.7	17.4	43.1	44.7	20.3	1.05	19.1	16.5	35.6	44.3
100 "	22.7	1.51	30.1	30.7	60.8	42.9	20.6	1.20	25.4	23.7	49.1	43.4

of the grain and the nitrogen content of the straw increased with increasing rate of applied fertilizer nitrogen. It is quite apparent in this data that the Elstow soil was able to provide only about one-half the amount of nitrogen of the Weyburn soil since total nitrogen uptake in the control plot crops was approximately 17 and 35 lbs N/acre, respectively.

On the three Black soils, the Hoey site far out-yielded either of the remaining two sites. Here, barley yields doubled from around 42 bu/acre to well over 80 bu/acre (Table 2.1.5) with added nitrogen. Such yields are probably the result of the high growing season rainfall (13.9 in) and the indigenous productive capacity of this Class I soil.

The relatively poor response to fertilizer N on the Yorkton soil is in accord with the very high level of available soil N. Rainfall at the site was adequate during the growing season but early fall frost may have reduced yields somewhat. The conductivity evident in the soil from fall samples was not apparent until the 3 ft depth in the spring samples, and this factor should not have greatly reduced yield potential.

The low overall yields and restricted responses to and recovery of applied nitrogen by all crops on the Naicam site (Tables 2.1.7 to 2.1.9) was undoubtedly due to the low rainfall obtained during the summer. Grain yields on the Grey Wooded Waitville soil site were extremely low, due to frost damage, but response to applied nitrogen was evident. This response was quite apparent in the total yield data. If a grain/straw ratio similar to other sites is assumed, yields would have ranged from around 25 bu/acre in the check to well over 50 bu/acre at higher nitrogen application rates.

Urea vs ammonium nitrate

There is very little indication in the data obtained as to any large consistent yield differences due to the two different nitrogen carriers. On most plots, differences were generally low, variable, and statistically not significant. The only indication of any differences was on the Hoey site where, at all but one application rate, yields from ammonium nitrate were slightly (1.5 to 6.5 bu/acre) higher than those from urea. Data relating to the total plant uptake of applied nitrogen show no consistent trends in recovery of the two sources except at the Hoey site where recovery of ammonium nitrate was consistently slightly higher than urea.

Fall vs spring application

Results with regard to differences arising from the two application times are quite small and variable. Yield and nitrogen uptake data from the two Dark Brown soils clearly indicate that fall-applied ammonium nitrate is at least equal to spring-applied. With urea there is a slight indication that fall-applied urea may have been slightly less effective when soil nitrate is low (Elstow soil) or low rates of nitrogen are applied.

On the Hoey site, yields and recoveries of fall-applied nitrogen were, in all cases, lower than those from the spring application (between three and eight bu/acre). Here nitrogen supplying power was probably pushed to the limit, since climate was so favorable, and when sources were less available it was reflected in a lower yield. No yield differences were noted in the Yorkton soil, but uptake of nitrogen was greater from the fall treatments than corresponding spring treatments. On the Naicam soil, in spite of the fact that both yields and response to nitrogen were low, fall-applied nitrogen produced barley yields that were lower than those from the spring application. Uptake of fall-applied fertilizer was correspondingly slightly lower. For wheat, only at the higher rate did spring nitrogen out-yield fall-applied nitrogen, while for rapeseed spring-applied urea slightly out-yielded fall-applied urea. Data from the Grey Wooded Waitville site indicate that a slightly more favorable response and nitrogen recovery was obtained from the spring broadcast application, particularly at the 100 lb N/acre rate.

Broadcast, side banded and seed placed nitrogen

Data from the three trials on the Naicam soil comparing different methods of applying nitrogen show no great yield differences between broadcast and side band nitrogen. Seed placed urea nitrogen definitely reduced crop yields at higher application rates, while seed placed ammonium-nitrate appeared to seriously reduce the yields of rapeseed only. It is apparent that the relative crop tolerance to seed placed nitrogen fell in the order - barley, wheat, and rapeseed.

CONCLUSIONS

Results from trials on six different soil types in 1974 showed no large differences between spring broadcast ammonium-nitrate and urea. Small differences in favor of ammonium-nitrate were apparent in data from a Deep Black Hoey soil, where growing season rainfall was high.

Differences, where they occurred, between spring and fall applied nitrogen were generally small. The largest difference, between 3 and 10 bu/acre of barley, were found in two Deep Black soils - a Hoey and a Naicam. Climatic conditions, in terms of rainfall, were quite different, with the Naicam site being dry through the growing season, while the Hoey site was quite wet.

Broadcast and side band nitrogen applications produced similar yields of barley, wheat and rapeseed on one soil type, while seed placed, particularly in the urea form, reduced yields at varying nitrogen application rates.

REFERENCES

Malhi, S.S. and M. Nyborg, 1974. A preliminary report on comparisons of fall and spring applications of nitrogen fertilizers. Dept. of Soil Science, University of Alberta, Edmonton, Alberta.

McGill, K.S., 1973. Urea vs. ammonium nitrate - A review. Proceedings, 1973 Soil Fertility Workshop, Saskatchewan Advisory Fertilizer Council, University of Saskatchewan, Saskatoon, Saskatchewan.

McGill, K.S., E.A. Paul and D.A. Rennie, 1973. Crop utilization and fate of fertilizer nitrogen in soil. II. 1973 Soil Plant Nutrient Research Report, Dept. of Soil Science, University of Saskatchewan, Saskatoon, Saskatchewan.

Partridge, J.R.D. and A.V. Ridley, 1974. Effect of nitrogen fertilizers applied in spring or fall on yields of barley. Proceedings, Eighteenth Annual Manitoba Soil Science Meetings, University of Manitoba, Winnipeg, Manitoba.

Paul, E.A., D.A. Rennie, H.J.V. Schappert and K.S. McGill, 1972. Crop utilization and fate of fertilizer nitrogen in soil. 1972 Soil Plant Nutrient Research Report, Dept. of Soil Science, University of Saskatchewan, Saskatoon, Saskatchewan.

2.2 Fate of Fertilizer Nitrogen

The large scale field plots showed that there were not many consistent differences in the yield of plant parts and of total nitrogen in the six plots studied except the Hoey soil where recovery of ammonium nitrate was slightly better than urea. To further investigate the fate of fertilizer nitrogen and to differentiate between the uptake of three forms of nitrogen, small plots (microplots) were established at the same sites as the larger ones. Fifty lbs N/acre (56 kg N/ha) were added to the cylinders in each of these sites and the crops grown. Four replicates were utilized. Because of the large expense in analyzing soils and plants for ^{15}N it was not possible to do a rate study. All treatments consisted of nitrogen added at the rate of 50 lbs/acre.

RESULTS

A comparison of Macro and Microplots

A concern in the interpretation of data from microplots comes from the possibility that they may not be representative of field conditions. Table 2.2.1 gives a comparison of the plant nitrogen yield in the two types of plots. In macro and microplots, except for the Yorkton site, the grain yield approximated 60% of the total plant yield. Because of the lower nitrogen content of straw, the grain nitrogen accounted for 66 to 75% of the total plant nitrogen in both types of plots.

The comparison between macro and microplots was conducted only at the 50 lb nitrogen rate. These rates do not show large differences between plots for the NH_4NO_3 and urea treatments applied in spring.

Table 2.2.1 Micro- and macroplot plant and nitrogen yield data

Soil and Treatment	Plant Yield (kg/ha)				Yield of Nitrogen (kg/ha)			
	Microplot		Macroplot		Microplot		Macroplot	
	Grain	Total	Grain	Total	Grain	Total	Grain	Total
<u>Naicam</u>								
Fall urea	1569	3451	1517	2896	27	46	28	45
Fall NH_4NO_3	1697	3137	1404	2749	29	41	26	45
Spring urea	1650	3177	1819	3164	31	46	34	49
Spring NH_4NO_3	1597	3367	1781	3003	31	49	33	48
<u>Hoey</u>								
Fall urea	4566	9610	3498	8004	64	88	46	73
Fall NH_4NO_3	3293	6733	3551	8461	46	65	53	78
Spring urea	4581	9552	3928	7728	63	91	64	84
Spring NH_4NO_3	3909	8361	3906	8379	55	77	61	89
<u>Elstow</u>								
Fall urea	1932	4080	2120	4272	25	36	29	37
Fall NH_4NO_3	1838	3608	2330	4662	24	30	33	45
Spring urea	1839	3837	2346	4442	25	37	39	51
Spring NH_4NO_3	2304	4335	2298	4428	30	40	35	45
<u>Yorkton</u>								
Fall urea	2314	4624	2061	4236	40	68	36	60
Fall NH_4NO_3	1595	3965	1937	3784	26	53	35	70
Spring urea	1701	4034	2136	4255	30	64	38	62
Spring NH_4NO_3	1414	3288	1889	3559	24	48	32	52

Table 2.2.1 Con't.

Soil and Treatment	Plant Yield (kg/ha)				Yield of Nitrogen (kg/ha)			
	Microplot		Macroplot		Microplot		Macroplot	
	Grain	Total	Grain	Total	Grain	Total	Grain	Total
Weyburn								
Fall urea	3957	7042	2470	4903	66	82	38	55
Fall NH_4NO_3	3440	5604	2959	5941	58	71	56	78
Spring urea	3309	4929	2540	5511	65	79	46	63
Spring NH_4NO_3	3525	6463	2776	5164	57	71	52	66
Waitville								
Fall urea		2113		3867		22		42
Fall NH_4NO_3		2422		4417		27		54
Spring urea		4115		3912		48		50
Spring NH_4NO_3		4318		4529		46		54

Microplots showed lower yields for the fall applied NH_4NO_3. The summary for the yield of nitrogen in the 1974 field plots treated at the 50 lb rate (Table 2.2.2) shows that on the average spring applied urea gave better N yield than the fall applied material in both micro and macroplots. The ammonium nitrate applied on the microplots had lower nitrogen yield than was shown by the macroplots. This was especially notable in the fall application. With this exception, there was generally a good relationship between the yield obtained on the micro and the macroplots.

Disposition of ^{15}N

Percent of the nitrogen derived from fertilizers (% NDFF)

The labelling of urea nitrogen and ammonia nitrate both in the ammonium and the nitrate ion of the same fertilizer made it possible to determine the specific fate of the three different forms of ferilizer nitrogen in the various plant parts and in the soil.

A comparison of the ^{15}N in the plant parts with that originally applied gives a measure of the percent of the nitrogen derived from the fertilizer. This parameter is independent of the yield and can be calculated for the various plant parts analyzed. Table 2.2.3 shows that the percent of the nitrogen derived from the various forms of fertilizer (% NDFF) did not differ between the grain and the straw indicating a similar uptake pattern for the fertilizer nitrogen and the soil nitrogen during the course of the year in one treatment. In all of the soils studied, a range of 12-60% of the nitrogen in the plant parts was derived from the fertilizer. The rest was obtained from the nitrogen present in soil.

Table 2.2.2 Comparison of N yield in the grain plus straw (kg N/ha) for the micro- and macroplots at the 50 lb N rate.

Form of N	Fall Applied		Spring Applied	
	Microplots	Macroplots	Microplots	Macroplots
Urea	57	52	61	66
NO_3^-	48	61	55	59

Table 2.2.3 Plant nitrogen distribution as measured with labelled fertilizer.

Soil	Treatment	Grain % NDFF	Straw % NDFF	Disposition of labelled N % of added			
				Grain	Straw	Roots	Plant total
Naicam	Fall urea	23.4	22.1	11.4±1.9*	7.7±1.5*	10	29.0
	Fall NH_4	24.2	24.0	14.3±3.5	5.1±0.6	6	25.4
	Fall NO_3	21.8	18.2	12.0±3.0	4.6±1.3	4	20.6
	Spring urea	30.2	25.5	16.9±0.9	6.7±0.9	7	30.6
	Spring NH_4	21.0	23.4	11.3±3.7	8.6±1.6	10	29.9
	Spring NO_3	44.8	41.4	27.2±0.8	11.8±2.0	13	52.0
Hoey	Fall urea	22.7	24.6	22.1±0.3	8.6±0.9	11	41.7
	Fall NH_4	23.0	23.6	16.6±3.2	8.1±1.6	7	31.7
	Fall NO_3	11.6	11.0	11.2±3.7	3.9±1.4	1	16.1
	Spring urea	23.5	24.3	25.1±2.0	10.9±1.2	6	42.0
	Spring NH_4	26.0	26.8	25.1±4.2	10.0±0.6	3	38.1
	Spring NO_3	36.6	35.0	33.9±2.8	12.5±1.2	7	53.4
Elstow	Fall urea	32.0	25.6	14.9±3.1	4.5±1.0	5	24.4
	Fall NH_4	31.0	31.2	15.9±1.3	3.5±0.3	5	24.4
	Fall NO_3	19.6	14.0	8.2±2.5	1.8±0.4	1	11.0
	Spring urea	32.3	27.6	14.4±2.2	5.5±1.5	5	24.9
	Spring NH_4	22.8	23.6	12.4±1.0	4.3±0.8	4	20.7
	Spring NO_3	65.6	62.0	32.4±0.6	9.6±0.7	15	57.0
Yorkton	Fall urea	15.7	17.8	11.1±0.8	9.2±1.6	13	33.3
	Fall NH_4	31.4	18.6	19.3±6.0	6.7±0.7	11	37.0
	Fall NO_3	1.4	1.8	0.88±0.5	1.1±0.5	2	4.0
	Spring urea	18.5	16.3	9.8±1.1	9.4±2.3	16	35.2
	Spring NH_4	13.4	17.2	6.5±1.3	7.2±1.3	6	19.7
	Spring NO_3	38.4	45.8	15.5±3.2	17.8±2.3	15	48.3

Table 2.2.3 Con't.

Soil	Treatment	Grain % NDFF	Straw % NDFF	Disposition of labelled N % of added			
				Grain	Straw	Roots	Plant total
Weyburn	Fall urea	19.6	23.3	21.9±2.1	6.4±0.5	12	40.3
	Fall NH_4	21.6	25.8	23.9±2.6	6.0±0.5	15	44.9
	Fall NO_3	16.4	17.2	18.2±4.7	4.4±1.2	5	27.6
	Spring urea	23.9	24.0	27.4±5.2	6.1±0.6	13	46.5
	Spring NH_4	20.8	19.8	20.8±1.3	4.6±0.3	9	34.4
	Spring NO_3	43.0	45.2	38.4±4.5	10.5±1.2	29	77.9
Waitville	Fall urea	19.5	2.8	7.9	1.4	.7	8.6
	Fall NH_4	25.0	5.0	11.3	2.0	.4	11.7
	Fall NO_3	14.2	5.8	8.3	3.6	.7	10.0
	Spring urea	36.0	7.1	29.3	4.0	1.2	30.5
	Spring NH_4	23.6	6.2	22.6	8.0	3.1	25.7
	Spring NO_3	35.0	6.6	23.5	4.5	12.0	35.5

*Standard Error

The % NDFF for the NH_4 and NO_3 ions was obtained by multiplying the values by two to account for the fact that only half the N was labelled.

In the Naicam site, 23% of the nitrogen in the plants came from fall applied urea. The plots with spring applied urea showed 30% of the plant nitrogen derived from the fertilizer. Only 22% of the plant nitrogen came from the labelled nitrate added in fall, but 45% of the plant nitrogen came from spring applied nitrate.

On the Hoey soil, spring application resulted in generally higher levels of % NDFF especially for nitrate, indicating the superiority of nitrate to all other forms of nitrogen when applied in spring. Spring application was equal to or higher in % NDFF to fall application in the remaining plots.

Recovery of Fertilizer Nitrogen in Plant Parts

The recovery of nitrogen in the grain, straw and roots is also shown in Table 2.2.3. The standard error of the mean for the grain and straw gives an estimate of the reproducibility of all of the analysis that went into these results. Generally an error of ±10% was noted for both the grain and the straw.

In the Naicam soil, 11-27% of the fertilizer nitrogen that had been added was found in the grain. The highest recovery was found for spring applied nitrate at 27% in the grain and 11.8% in the straw, with 13% in the roots. In general, the percent of nitrogen in the roots was equal to that in the straw. A great deal of experience has shown that ^{15}N analysis of roots gives more variable results than the analysis of grain or straw because of the presence of dead roots and soil contamination. In this experiment, however, the percent utilization as measured by roots, varied with fertilizer type in a similar manner to that of the aboveground materials, i.e. fall nitrate gave the lowest amounts of nitrogen whereas spring nitrate gave the greatest.

In the Naicam soil, fall applied urea gave a greater total percent uptake (29%) than the NH_4 (25%) or NO_3 (21%). In spring the situation was reversed and nitrate gave by far the greatest recovery (52%). It is of special interest that ammonium and urea gave equivalent plant uptake values in spring. The Hoey soil gave similar results with urea giving a higher recovery in fall, and nitrate a very low value. In spring, urea and ammonia were again equal in recovery both being lower than that of nitrate.

The Yorkton site lost nearly all of its fall applied nitrate nitrogen but showed a reasonably high recovery of urea and ammonia. These data indicate that under the wet fall and spring conditions that occurred in 1973-74 the nitrate ion was exceptionally sensitive to loss under the specific conditions encountered in the cylinders. Denitrification rather than leaching of the NO_3 is indicated. Excess movement of water through the profile while urea was present should have resulted in the loss of some of this material. Urea on hydrolysis would form ammonia. This could account for the somewhat similar recoveries for ammonia and urea.

In the Weyburn soil, the fall urea and ammonia gave 40-44% recovery, whereas nitrate gave 28%. Urea and ammonia showed a plant uptake of 46 and 35%, respectively. The nitrate added in spring went primarily into the plant material for a recovery of 78%. The Waitville soil received an early frost, thus there was no separation into grain and straw nitrogen. Uptake values are reported for total plant material only. All forms of nitrogen added in the fall had very low uptake and all forms in spring showed a uniform uptake approximating 32 to 35% of the nitrogen.

Normally roots are not included in plant uptake values resulting in the common calculation that 25-50% of the total nitrogen is recovered in aboveground plant materials. These data corroborate the low recovery of fertilizer nitrogen in the grain, straw and roots. What is especially noteworthy is the fact that nearly as much nitrogen was left behind in the straw and roots as was removed by the grain showing the high residual value of fertilizer nitrogen if straw is incorporated into the soil.

Recovery of ^{15}N in the Soil

The use of ^{15}N made it possible to follow the disposition of fertilizer N in the soil (Table 2.2.4). In the Naicam soil there was 2.5 times as much urea nitrogen left in the soil at harvest as there was in the grain. In all cases, the nitrogen removed in the grain accounted for less than 40% of the added nitrogen. This further stresses the need for long term planning in the application of fertilizer nitrogen for large residual N values can occur. Fall nitrate generally resulted in very little nitrogen left in the soil.

The 1972-73 data reported earlier indicated that although urea generally showed the lowest percent of plant uptake, a great proportion of the urea nitrogen was retained in the soil. In the 1974 series of experiments reported here, the ammonium ion appeared to show the greatest soil recovery values. Although this ion did not show a higher percent uptake by the plant materials, generally a larger proportion of ^{15}N labelled ammonium could be found in the soil. Thus, in the Naicam soil, application of labelled ammonium in the fall resulted in 25%

Table 2.2.4 Soil nitrogen distribution as measured with labelled fertilizer.

Soil	Treatment	Disposition of labelled N % of added				
		0-6" Soil	6-12" Soil	Total Soil	Total Recovery	Loss
Naicam	Fall urea	38.58	3.3	41.88	70.88	29.12
	Fall NH_4	57.05	2.75	59.80	85.2	14.8
	Fall NO_3	6.84	1.7	7.54	28.14	71.86
	Spring urea	31.59	2.02	33.61	64.21	35.79
	Spring NH_4	39.2	3.04	42.26	72.16	27.84
	Spring NO_3	30.4	3.44	33.84	85.84	14.16
Hoey	Fall urea	29.28	2.77	32.05	73.75	26.25
	Fall NH_4	43.01	1.29	44.30	76.00	24
	Fall NO_3	24.00	4.92	28.92	45.02	54.98
	Spring urea	50.49	5.23	55.72	97.72	2.28
	Spring NH_4	36.90	1.65	38.55	76.65	23.35
	Spring NO_3	16.14	4.19	20.33	73.73	26.27
Elstow	Fall urea	34.98	7.79	42.77	67.17	32.83
	Fall NH_4	45.10	8.53	53.63	78.03	21.97
	Fall NO_3	5.57	7.45	13.02	24.02	75.98
	Spring urea	31.94	9.92	41.86	66.76	33.24
	Spring NH_4	46.14	9.99	56.13	76.83	23.17
	Spring NO_3	16.00	8.98	24.98	81.98	18.02
Yorkton	Fall urea	27.51	5.29	32.80	66.1	33.9
	Fall NH_4	35.16	5.45	40.61	77.61	22.39
	Fall NO_3	.60	.71	1.31	5.29	94.71
	Spring urea	29.33	1.80	31.13	66.33	33.67
	Spring NH_4	19.05	1.13	20.18	39.88	60.12
	Spring NO_3	15.30	2.70	18.00	66.3	33.7

Table 2.2.4 Con't.

Soil	Treatment	Disposition of labelled N % of added				
		0-6" Soil	6-12" Soil	Total Soil	Total Recovery	Loss
Weyburn	Fall urea			36.47	76.77	23.23
	Fall NH_4			54.17	99.07	.93
	Fall NO_3			4.77	32.37	67.63
	Spring urea			34.23	80.73	19.27
	Spring NH_4			50	84.4	15.6
	Spring NO_3	16.24	10.64	26.88		
Waitville	Fall urea	40.24	-	40.24	48.84	51.16
	Fall NH_4	51.19	.48	51.67	63.37	36.63
	Fall NO_3	4.34	-	4.34	14.34	85.66
	Spring urea	54.08	7.38	61.46	91.96	8.04
	Spring NH_4	54.80	1.83	56.63	82.33	17.67
	Spring NO_3	24.53	2.38	26.91	62.41	37.59

uptake by plants with 60% remaining in the soil for a total recovery of 85% and a loss of 15%. Conversely, the nitrate ion in ammonium nitrate applied in the fall had a 21% plant uptake and only 7% remaining in the soil for a total recovery of 28% and a loss from the soil system of 72%. Spring nitrate because of the high plant uptake with a reasonable amount of nitrogen left behind in the soil showed an 86% recovery with only 14% loss. The Hoey soil showed similar data with fall applied nitrate losing 55% of the nitrogen added but spring urea showing a loss of only 2%.

The great range in loss figures ranging from 0.93% for the ammonium treatment in the Weyburn soil to 98% loss in the Yorkton soil shows that nitrogen losses are greatly dependent on the time of addition, the type of fertilizer used, and the soil moisture content. It was noted that the cylinders while in the field retained a greater portion of the water from the snow melt than did the rest of the field. This could account for the lower plant nitrogen yield and the high loss values for the NO_3 ion in the microplots.

Ammonium nitrate often used as the standard fertilizer for comparison of other fertilizers is composed of the two fractions, ammonium and nitrate. Plant yield analysis cannot differentiate between these two ionic species. These data clearly show that in spring the nitrate ion is the superior fertilizer. The same mobility and the ease of transformations which leads to high recovery in spring can lead to great losses of fall applied nitrate.

The data for all six trials are summarized in Table 2.2.5. Fall applied urea and ammonia both had 29% fertilizer nitrogen uptake by the plants, fall applied nitrate had only 11%. The situation was reversed in spring with the average of all six trials showing that

Table 2.2.5 Fertilizer N recovery by plants (grain, roots, straw) and nitrogen remaining in the soil.

Form of N	Fall Applied			Spring Applied		
	Plants	Soil	Total	Plants	Soil	Total
	%			%		
Urea	29	37	66	34	41	75
NH_4^+	29	52	81	28	44	72
NO_3^-	11	11	22	53	25	78
Average	23	33	56	38	37	75

urea had a 34% uptake of nitrogen in the grain, roots and straw, ammonia resulted in 28% and nitrate 53%. The summary table showed 37% of the urea and 52% of the ammonium remained in the soil after harvest. Thus urea applied in the fall had a 66% recovery but only 22% of the fall applied nitrate was present in the soil plus plant materials. In spring all forms of nitrogen showed fairly similar total nitrogen balance sheets with only a slight superiority for the nitrate treatment which showed a high plant recovery and lower residual soil nitrogen values.

CONCLUSIONS

The ^{15}N assay of the plant parts and soils from the 1974 experiments reported herein indicated that plant utilization of fertilizer nitrogen applied either as urea or ammonium in the fall averaged 30% in contrast to 11% for the nitrate source. Nitrates were the most effective when applied in the spring with 50% recovery compared to approximately 30% for the other two sources. The ^{15}N experiments, therefore, differ from the large scale field plots which showed no yield differences between nitrogen sources in the fall. The explanation for the difference probably lies with the difference between the micro and macroplots. During the wet fall of 1973 and the early spring of 1974 when there was a great deal of rainfall, the cylinder retained more moisture than the field plots. The nitrate ion in the microplots, therefore, was subject to a greater amount of leaching and denitrification than in the field plots. This is verified by the fact that the yield data for the microplots was similar to that of the macroplots in the spring, but not in the fall. Yield data can just give an average for ammonium nitrate but the tracer data separated the two ions.

The nitrogen balance sheet verifies a great deal of other ^{15}N research in that only a low percentage of the added nitrogen is utilized by the plant. The low plant utilization of fall applied fertilizer (23%) should be great cause for worry. It is of interest that an additional 33% of the fertilizer nitrogen still remained in the soil for future plant use. However, this still indicates that nearly 50% of the nitrogen applied in the fall for the 1974 growing year was lost from the soil system. Spring application resulted in much higher recoveries especially for the nitrate ion with a total plant uptake value of 38% of the fertilizer nitrogen applied and an equivalent amount left in the top foot of the soil. Some additional fertilizer could be left in the soil beneath this depth. This would not be expected to be a great deal indicating that even for the spring applied material, 25% of the fertilizer nitrogen was lost from the soil-plant system. These very high loss figures should be cause for further consideration because the wastage of plant nutrients results in the wastage of money and energy required in the production of fertilizer. The possibility of environmental contamination by the fertilizer itself or degradation products also must be considered.

The high loss values also must lead one to question the possibility of soil nitrogen loss during the summerfallowing process. The fallow process builds up a great deal of nitrate nitrogen and also accumulates moisture. The combination of these have been shown in this study to lead to extensive losses of nitrogen. It is possible that the losses of soil nitrogen are as high as those of fertilizer nitrogen indicating that agronomic practices involving cropping in Western Canada should take into account the retention and conservation of soil nitrogen to an equal extent as the conservation of moisture.

3. DETAILED STUDIES ON THE NITROGEN AND PHOSPHORUS NUTRITION OF FABABEANS (*Vicia faba*)

INTRODUCTION

Fababeans are a relatively new crop on the Canadian prairies. The purpose of this study was to examine the effects of soil nitrogen (N) and phosphorus (P) fertility levels on dry matter production, and on the N and P nutrition of fababeans under prairie soil and climatic conditions. The ability of fababeans to symbiotically fix atmospheric N under these conditions was of particular interest in this study.

Experiments were conducted in the field on a single site. Inorganic N and P fertilizers were applied to provide a range of N and P fertility levels. Crop use efficiency of the applied N and P was determined using ^{15}N and ^{32}P-labelled fertilizer materials. Symbiotic N fixation by the inoculated fababean crop was measured in the field by the acetylene reduction method and by difference in total crop N uptake between fababeans and an adjacent non-leguminous crop barley.

METHODS AND MATERIALS

Site and Soil Description

The site was 10 miles east of St. Louis, Saskatchewan (SE5-45-25-W2; Mr. Selmar Nyaa) on stubble land previously sown to barley. The soil was a deep black Orthic Chernozem of clay loam surface texture, belonging to the Hoey Association (Table 3.1). It was formed from glacio-lacustrine parent material

Table 3.1. Physical and chemical properties of the Hoey soil at seeding (average of 2 samples each consisting of 4 cores).

Depth (in.)	Texture	pH (sat. paste)	Cond. (mmhos/cm)	lb/acre $NaHCO_3$ extractable		
				NO_3-N	P	K
0-6	Clay loam	6.6	0.3	9	14	575
6-12	Clay loam	6.8	0.2	7	6	305
12-24	Silty clay	7.2	0.5	12	7	555

in an area of gently sloping topography. Soil test data indicated that the soil was low in plant available NO_3-N and P prior to seeding. Fertilizer recommendations based on soil test data for fababeans were 20 lb N and P_2O_5/acre. For barley, they were 45 lb N/acre and 35 lb P_2O_5/acre. Soil moisture conditions at seeding and during crop growth were excellent. Between seeding and harvest, 13.9 inches of rainfall were recorded at the site.

Experimental Layout

Prior to seeding on June 8, the site was cleared of loose straw and roto-tilled. Nitrogen as granular NH_4NO_3 (34-0-0) was broadcast at rates of 0, 25, 50 and 100 lb N/acre to the four adjacent main plots, each 80 feet long by 28 feet wide. Liquid $^{15}NH_4$ $^{15}NO_3$ containing 1.4% ^{15}N atom excess was sprayed in a four foot wide strip placed lengthwise across each of the 25 and 50 lb N/acre main plots instead of the granular 34-0-0. Treflan and Avadex were then applied to areas of the main plots that were to be sown to fababeans and barley respectively and the site again roto-tilled.

Crops were seeded in 28 foot long rows across the width of the main plots using a four row, V belt, disc seeder set for 9 inch row spacings. Fababeans (<u>Vicia</u> <u>faba</u> var Diana) were slurry mixed with 'Nitragen' inoculum and seeded to a depth of 3 inches at a rate of 150 lb/acre. Within each N main plot there were six seed-placed P treatments replicated five times in a randomized complete block design. The two row P treatments (subplots) were:

i) 0, 60 and 90 lb P_2O_5/acre applied as granular $NH_4H_2PO_4$ (11-55-0) to both rows, and

ii) 15, 30 and 60 lb P_2O_5/acre with 11-55-0 in one row, and crystalline ^{32}P-labelled $NH_4H_2PO_4$ (11-60-0)* in the second.

At one end of the main plots, Bonanza barley was seeded at 80 lb/acre with a single seed-placed P treatment of

*Supplied courtesy of the Tennessee Valley Authority, Muscle Shoals, Alabama.

11-55-0 at 60 lb P_2O_5/acre. There were five two-row barley replicates (subplots) per N main plot. Plots were keptweed-free throughout the experiment.

Sampling and Analysis of Plant Material

Both crops were harvested between September 5 and 9, after the barley had matured. Above ground plant samples, each consisting of one and two 8 foot row lengths were taken from each of the fababean and barley N-P subplots respectively ('yield' samples). Samples were dried at 60C and threshed. Total and bean/grain dry matter (D.M.) yields were measured.

Duplicate 0.5 g subsamples of dried, ground (<2 mm) bean/grain and straw material were wet digested on a Technicon BD 40 block digestor using an H_2O_2-Kjeldahl digestion procedure[1]. The aqueous digested samples were diluted 25:1 on an autodilutor and then colorimetrically analyzed for total Kjeldahl N (as NH_4-N) and orthophosphate on a Technicon AutoAnalyzer II System[1]. The fababean bean samples were assayed for ^{32}P activity using the Geiger-Müller (N.C. D48 gas flow counter) planchet system for counting solid samples[2]. Counting time was adjusted for a minimum of 10^4 counts per sample from the ^{32}P-labelled treatments.

Phosphorus 'A' values and percentage plant P derived from the fertilizer (% Pdff) were calculated from the following formulae using orthophosphate content and ^{32}P activity of the bean samples.

'A' value (lb P/acre) = $(Sa_f/Sa_p - 1) \cdot X$

and % Pdff = $(Sa_p/Sa_f) \cdot 100$

where Sa_f = Specific activity of the fertilizer

Sa_p = Specific activity of the plant material

and X = Rate of fertilizer P applied (lb P/acre).

The percentage (%) crop use of applied P was calculated as follows, assuming that % Pdff was the same for straw and bean material from the same plant:

$$\% \text{ use of applied P} = \frac{\% \text{ Pdff} \cdot \text{crop uptake of P (beans + straw: lb P/ac)}}{X}$$

Additional above ground plant samples, each consisting of two 2 foot row lengths were taken from the ^{15}N-labelled strips on the 25 and 50 lb N/acre main plots. 0.4 g subsamples of dried ground (<1 mm) bean/grain and straw material from the ^{15}N strips on each of the 0 and 60 lb P_2O_5/acre fababean subplots and the barley subplots were analyzed for plant N by standard Kjeldahl procedure followed by steam distillation of the ammonia into 2% boric acid and electrometric titration[2]. After concentration by vacuum distillation, these solutions were assayed for % ^{15}N atom abundance on a mass spectrometer (MAT GD 150). Samples from the non ^{15}N-labelled areas of these same subplots were similarly analyzed to establish background % ^{15}N atom abundance. The % ^{15}N atom excess for each ^{15}N labelled sample was calculated as the difference between these two sets of figures. The % ^{15}N atom excess of the labelled N fertilizer was similarly determined.

The % plant N derived from the fertilizer (% Ndff) and the % crop use of the applied N were calculated from the following formulae:

$$\% \text{ Ndff} = \frac{\% \ ^{15}\text{N atom excess (plant)}}{\% \ ^{15}\text{N atom excess (fertilizer)}} \cdot 100$$

and % use of applied N

$$\text{(beans/grain + straw)} = \frac{(\% \text{ Ndff} \cdot \text{N uptake})_{\text{Beans/grain}} + (\% \text{ Ndff} \cdot \text{N uptake})_{\text{Straw}}}{\text{rate of N applied (lb N/acre)}}$$

Values for N uptake (lb N/acre) were calculated from the yield and tissue N content of the 'yield' samples.

Data for the fababean part of the experiment were statistically analyzed as a split plot design of 4 N main plots, 6 P subplots and 5 replicates. The barley data was statistically analyzed as a simple randomized complete block design of 4 N treatments and 5 replicates. Where the F test proved significant at the 5% level or less, the results were further analyzed using Duncan's Multiple Range test[3].

Measurements of Symbiotic N Fixation

Symbiotic N fixation was measured in the field by the acetylene reduction method[4] on the 0 and 50 lb N/acre - 60 lb P_2O_5/acre fababean plots. Measurements were made at weekly intervals from July 9 to harvest. Values for each plot at each sampling date represented the average of acetylene reduction determinations made on two 2½ inch diameter cores each taken from the top 6 inches of soil around the nodulated portion of a fababean root. (There was no evidence of nodulation outside this volume of soil.)

The contribution of symbiotic N fixation to total N uptake in the above ground fababean material over the growing season was calculated from the difference in crop N uptake (total above ground material at harvest) plus residual (harvest - seeding) soil NO_3-N to 48 inches (see next sub-section) between fababeans and barley grown on the same site at the same rate of N and P application.

Sampling and Analysis of Soil

Prior to fertilizer application on June 8, a composite soil sample, consisting of four 2 inch diameter cores, was taken from each half of the site at depths of 0-6, 6-12, 12-24, 24-36 and 36-48 inches. Similarly at harvest, four composite soil samples (2 cores each) were taken from the fababean and barley areas of the 0 lb N/acre main plot, and a single composite sample from each of the fababean and barley areas of the 25, 50 and 100 lb N/acre main plots. All soil samples were analyzed for sodium bicarbonate extractable NO_3-N and for oven dry (105C) soil moisture content. Initial soil samples down to 24 inches were also analyzed by the Saskatchewan Soil Testing Laboratory for pH, salinity, texture and sodium bicarbonate extractable P and K.

Soil moisture values were converted to inches of water using bulk density values of 1.15, 1.25, 1.35, 1.45 and 1.45 g/cm^3 for the respective profile depths. This allowed calculation of inches of water used by the crops, based on the differences in soil moisture content down to 48 inches between seeding and harvest plus any intervening rainfall measured at the site.

RESULTS

All fababean plants examined from July 9 on showed excellent nodulation of the roots in the top 6 inches of soil. When harvested, the fababeans were 3.5 to 4 feet high. Bean pod formation was complete on at least the lower half of the plants but the pods had only just started to ripen.

Effects of Different N Fertility Levels

For the fababeans without N fertilizer application, bean and total dry matter (D.M.) yields (averaged for the 6 P treatments) were 1470 and 7580 lb/acre respectively (Table 3.2). Application of the maximum rate of 100 lb N/acre increased these yields by 29 and 9%. Each successive increment of fertilizer N resulted in a small decrease in tissue N content, with an overall decline from 5.71 to 5.53% for the beans and from 1.45 to 1.27% for the straw. At the same time, bean and total N uptake progressively increased from 84 to 105 and from 172 to 185 lb N/acre, a 25 and 8% increase respectively. Although N application depressed tissue P content from 0.69 to 0.62% for the beans and from 0.156 to 0.104% for the straw, it had little effect on overall P uptake by fababeans. Effects of applied N on D.M. yield and on plant N and P for fababeans were similar for both beans and straw. However, these N effects generally were statistically significant for the bean data only.

The barley data in Table 3.3 was included as a comparison of the effects of applied N on a leguminous and a non-leguminous annual crop. For the barley, each increment of N

Table 3.2. Effect of applied nitrogen on dry matter production and on the nitrogen and phosphorus nutrition of fababeans (average of 6 P treatments and 5 replicates).

N applied lb N/acre	Dry Matter lb/acre		Plant Nitrogen Tissue Content (%)		Plant Nitrogen Uptake lb N/acre		Plant Phosphorus Tissue Content (%)		Plant Phosphorus Uptake lb P/acre	
	Beans	Total†	Beans	Straw	Beans	Total†	Beans	Straw	Beans	Total†
0	1470b‡	7580	5.71a	1.45	84b	172	.69a	.156a	10.1b	19.6
25	1600b	8000	5.62ab	1.43	90b	181	.67a	.134a	10.6ab	19.2
50	1720ab	8030	5.53b	1.35	95ab	181	.66a	.134a	11.3ab	19.8
100	1900a	8250	5.53b	1.27	105a	185	.62b	.104b	11.7a	18.4
Level of Significance	<5%	NS*	<1%	NS	<5%	NS	<1%	<1%	<5%	NS

Table 3.3. Effect of applied nitrogen on dry matter production and on the nitrogen and phosphorus nutrition of barley (60 lb P_2O_5/acre applied; average of 5 replicates).

N applied lb N/acre	Dry Matter lb/acre		Plant Nitrogen Tissue Content (%)		Plant Nitrogen Uptake lb N/acre		Plant Phosphorus Tissue Content (%)		Plant Phosphorus Uptake lb P/acre
	Grain	Total†	Grain	Straw	Grain	Total†	Grain	Straw	Total†
0	1690d‡	3360d	1.50b	.74	25.1c	37.3c	.416	.261a	11.3c
25	2180c	4570c	1.47b	.71	32.0bc	49.1bc	.417	.217a	14.2b
50	2670b	5470b	1.45b	.65	38.8b	57.1b	.406	.180b	15.9b
100	3330a	6990a	1.70a	.87	57.4a	89.6a	.407	.175b	20.0a
Level of Significance	<1%	<1%	<1%	NS*	<1%	<1%	NS	<1%	<1%

† Above ground material.

‡ Mean values followed by the same letter were not statistically different at the indicated levels of significance.

* Not statistically significant.

resulted in a large, highly significant increase in D.M. yield and in plant N and P uptake. With the application of 100 lb N/acre, grain and total D.M. production doubled from 1690 to 3330 lb/acre and from 3360 to 6990 lb/acre respectively. Similarly grain and total N uptake more than doubled from 25.1 to 57.4 lb N/acre and from 37.3 to 89.6 lb N/acre. Total P uptake increased from 11.3 to 20.0 lb P/acre. Bean and straw N contents, which averaged 1.53% and 0.74% respectively, declined with increasing rates of N except at 100 lb N/acre. Tissue P content also declined with N application.

Despite large differences in the degree of fababean and barley response to applied N, the % crop use of applied N in the above ground plant material was very similar for both crops (Table 3.4). With 60 lb P_2O_5/acre, % use of applied N by fababeans and barley averaged 25.3 and 24.0% respectively.

Table 3.4. Percentage crop use of applied nitrogen by fababeans and barley (average of 5 replicates).

N applied lb N/acre	P applied (lb P_2O_5/acre)		
	Fababeans		Barley
	0	60	60
25	21.4±2.4	24.9±5.0	19.4±5.8
50	28.3±7.6	25.7±8.5	28.5±8.2

At harvest NO_3-N content in the soil down to 48 inches was greater under barley than fababeans at all rates of N application: it averaged 66 and 51 lb NO_3-N/acre respectively (Table 3.5). Although these levels were higher than the 38 lb NO_3-N/acre recorded at seeding, residual effects of the applied N on soil NO_3-N were apparent only under barley. Some 18% of the total NO_3-N to 48 inches was in the top 12 inches of soil under barley compared with 41% under fababeans.

Table 3.5. Effect of crop and N application on the $NaHCO_3$-extractable NO_3-N content of the Hoey soil at harvest.

Depth (in.)	N application (lb N/A)									
	Barley					Fababeans				
	0*	25	50	100	Ave	0*	25	50	100	Ave
0-6	11	5	4	2	6	15	16	13	11	14
6-12	7	6	2	10	6	8	8	3	8	7
12-24	17	22	38	36	28	7	8	14	6	9
24-36	14	18	10	14	14	12	8	10	10	10
36-48	10	14	10	14	12	11	10	14	10	11
Total to 48"	59	65	64	76	66	53	50	54	45	51

*Average of 4 samples

The weekly acetylene reduction N fixation data is presented in Figure 3.1. Symbiotic N fixation by the fababeans 5 weeks after seeding was less than 0.2 lb N/acre/day. It progressively increased to a maximum rate of about 2.2 lb N/acre/day 8 weeks later. Initially N fixation was higher with no applied N. This situation subsequently was reversed, with plants on the 50 lb N/acre plots showing higher rates of fixation. However, the sum of N fixed over the season as measured by acetylene reduction (Table 3.6), was the same for the 0 and 50 lb N/acre plots (62 lb N/acre).

Symbiotic N fixation values calculated from the difference in crop N uptake plus residual soil NO_3-N at harvest between fababeans and barley, together with the data from which these values were derived, are given in Table 3.6. These fababean N fixation values were similar for the 0, 25 and 50 lb N/acre plots, averaging 128 lb N/acre/season. However, for the 100 lb N/acre plots, N fixation was only half this value.

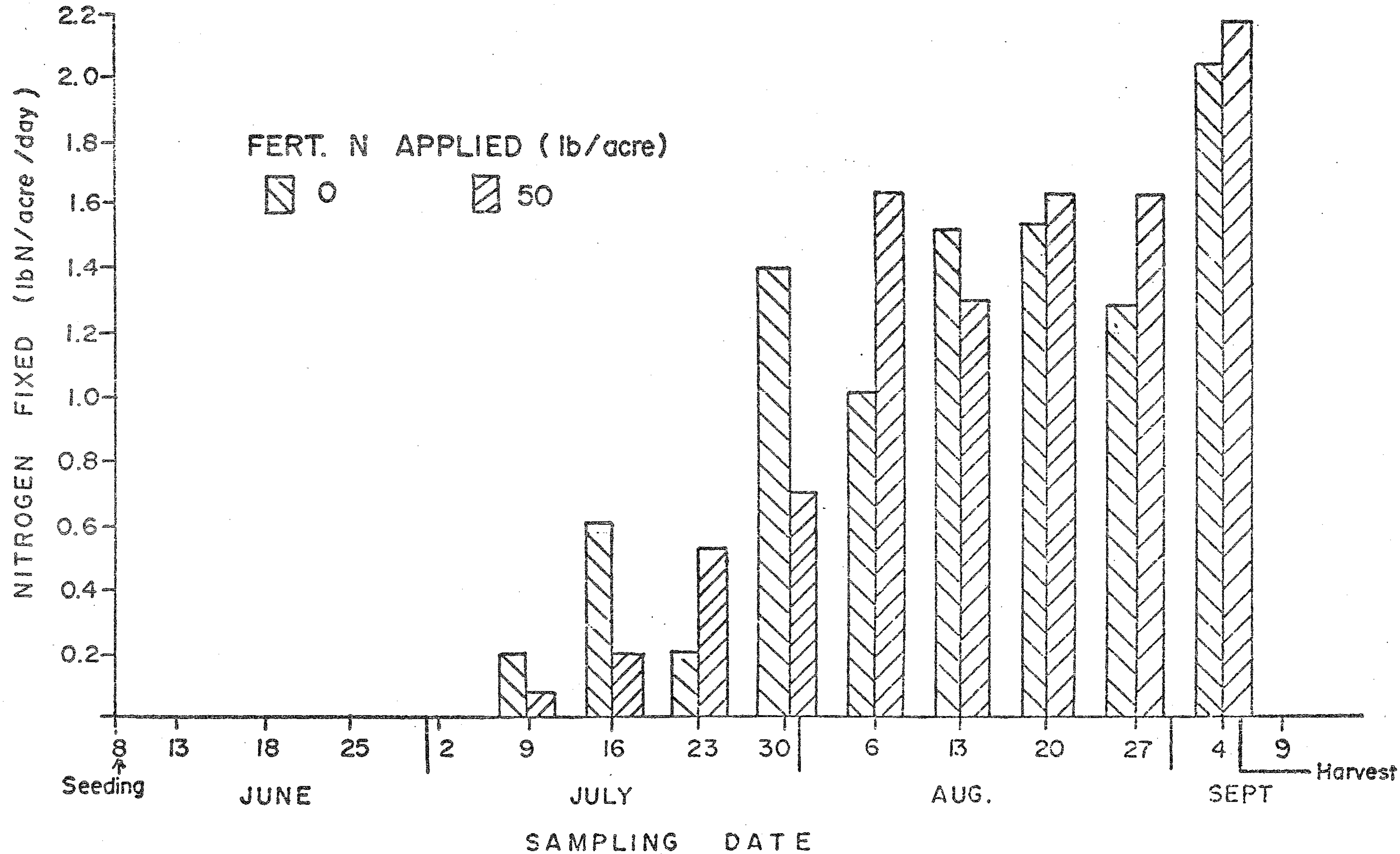


Figure 3.1. Seasonal pattern of nitrogen fixation by fababeans as affected by applied nitrogen (acetylene reduction method: average of 5 replicates).

Table 3.6. Effect of applied nitrogen on crop nitrogen uptake and residual soil NO_3-N† for fababeans and barley, and on fababean nitrogen fixation (lb/acre/season).

N applied lb N/acre	Fababeans*			Barley*			F'bean N fix.	
	Crop N Uptake 1	Residual† Soil NO_3-N 2	Total 1 + 2 3	Crop N Uptake 4	Residual† Soil NO_3-N 5	Total 4 + 5 6	F'bean N- Bly. N (3-6)	Acetyl. Reduc.
0	173±28	15	188	37± 3	21	58	130	62±15
25	189±15	12	201	49± 6	27	76	125	ND
50	195±58	16	211	57±11	26	83	128	62± 6
100	187±30	7	194	90±17	38	128	66	ND

† NO_3-N to 4 ft: harvest-seeding (38 lb N/acre)

* Same site - 60 lb P_2O_5/acre applied

ND - Not determined

There was little difference in water use by fababeans and barley (Table 3.7). Similarly, water use by these crops appeared to be unaffected by rate of N application. Water was probably not a major factor limiting crop growth in this experiment.

Table 3.7. Effect of N application on water use by fababeans and barley.

N level (lb N/acre)	Barley (inches of water)	Fababeans
0	15.4	16.3
25	13.5	15.4
50	16.4	15.2
100	15.6	15.6
Ave	15.2	15.6

†Average of 4 samples.

Effects of Different P Fertility Levels

Without P fertilizer, bean and total D.M. yield for fababeans (averaged for the 4 N treatments) were 1790 and 7780 lb/acre respectively (Table 3.8). Application of P resulted in a slight decrease in bean D.M. yield to a low of 1690 lb/acre recorded at the 30, 60 and 90 lb P_2O_5/acre treatments. However, for total D.M. yield there was a small progressive increase with applied P to a maximum value of 8340 lb/acre. Application of P had no effect on tissue N content. Tissue P content, on the other hand, increased from 0.62 to 0.69% in the beans and from 0.116 to 0.151% in the straw with increasing rates of P application. The net result was a 21% increase in total P uptake, from 17.9 to 21.7 lb P/acre. Effects of applied P were statistically significant for the tissue P content and total P uptake data only. Statistical analysis revealed no evidence of an N-P interaction effect for any of the crop parameters shown in

Table 3.8. Effect of applied phosphorus on dry matter production and on the nitrogen and phosphorus nutrition of fababeans (average of 4 N treatments and 5 replicates).

P applied lb P_2O_5/acre	Dry Matter lb/acre		Plant Nitrogen Tissue Content (%)		Plant Nitrogen Uptake lb N/acre		Plant Phosphorus Tissue Content (%)		Plant Phosphorus Uptake lb P/acre	
	Beans	Total†	Beans	Straw	Beans	Total†	Beans	Straw	Beans	Total†
0	1790	7780	5.62	1.40	100	184	.62d‡	.116c	11.0	17.9b
15*	1770	8000	5.55	1.36	98	182	.63cd	.119c	11.0	18.3b
30*	1690	8010	5.59	1.34	94	178	.65bc	.127bc	11.0	18.9ab
60*	1420	7500	5.60	1.33	79	160	.69a	.136ab	9.8	18.0b
60	1690	8180	5.61	1.41	95	186	.68ab	.143ab	11.4	20.7ab
90	1690	8340	5.61	1.40	95	188	.69a	.151a	11.7	21.7a

†Above ground material.

‡Mean values followed by the same letter were not statistically different at the 5% level of significance.

*P treatments receiving crystalline ^{32}P-labelled $NH_4H_2PO_4$ (12-60-0).

Tables 3.2 and 3.8. Yield based data for the plots receiving 60 lb P_2O_5/acre as crystalline ^{32}P-labelled 12-60-0 differed noticeably from results for plots receiving the same level of P applied as granular 11-55-0 (Table 3.8). Values for bean and total D.M. yield and for total N and P uptake for this treatment were appreciably lower than for all other P treatments.

Phosphorus 'A' values (averaged for the 4 N treatments) increased from 108 to 138 lb P/acre with increasing P application (Table 3.9) with values at the 60 lb P_2O_5/acre rate being significantly greater than at the 15 lb rate. The reverse was true for the % crop use of applied P, with values decreasing from 16.7 to 11.2%. Although 'A' values (averaged for the 3 P treatments) differed significantly with rate of N application, no clear trend emerged. The rate of applied N apparently had little effect on % crop use of applied P and there was no evidence of an N-P interaction effect.

DISCUSSION

At equal rates of applied P and without applied N, total D.M. yield for fababeans was more than double that of the adjacent barley crop (Figure 3.2). However, barley responded strongly to each increment of applied N giving approximately a 100% increase in grain and total D.M. yields at the maximum rate of 100 lb N/acre. This clearly indicated that the unfertilized Hoey soil was very deficient in plant available N for non-leguminous crops.

The much higher D.M. yield and N uptake of fababeans without N fertilizer and the much smaller yield response of this crop to applied N was undoubtedly due to the ability of fababeans to obtain as much as 75% of their N (128 lb N/acre in the above ground plant material) by fixation of atmospheric N (Table 3.6). Nonetheless, applied N did have a significant beneficial effect on bean D.M. yield and N uptake (Table 3.2). Evidence from both sets of N fixation data strongly suggests that total N fixation by fababean during the season was not

Table 3.9. Phosphorus 'A' values and the percentage crop use of applied phosphorus by fababeans.

Effect of applied phosphorus (4 N levels x 5 replicates)			Effect of applied nitrogen (3 P levels x 5 replicates)		
P applied lb P_2O_5/acre	'A' value lb P/acre	% use of applied P*	N applied lb N/acre	'A' value lb P/acre	% use of applied P*
15	108b†	16.7a	0	124a†	13.9
30	121ab	14.4ab	25	110b	15.2
60	138a	11.2b	50	148a	12.6
			100	106b	14.8

*Above ground material.

†Mean values followed by the same letter were not statistically different at the 5% level of significance.

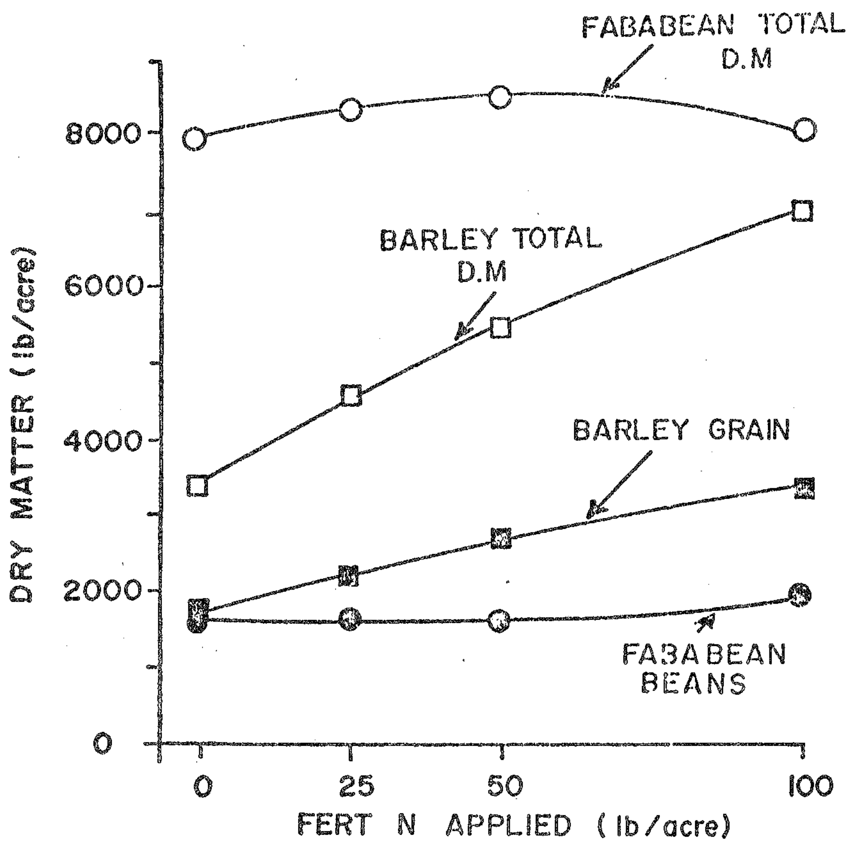


Figure 3.2. Effect of nitrogen on dry matter production for fababeans and barley on the same site (60 lb P_2O_5/acre applied; average of 5 replicates).

affected by N applications of up to 50 lb N/acre. However, further increments of applied N apparently had a marked detrimental effect on N fixation, though not on crop yield response to the applied N.

Fababean N rixation was in fact adversely affected by lower rates of applied N, but only during the first 4 to 5 weeks after initiation of the fixation process (Figure 3.1). This may have been because some inorganic fertilizer N remained in the root zone. Above a certain level both NH_4-N and NO_3-N may inhibit symbiotic N fixation. However, later in the season, probably after depletion or removal of any remaining inorganic fertilizer N (at harvest there was no evidence of any residual effect of fertilizer N on soil NO_3-N under fababeans: Table 3.5, fababean plants on plots receiving these lower rates of applied N were more than able to compensate for the earlier reduction in N fixation. This may have occurred because the applied N engendered faster growth of fababeans, and hence greater photosynthetic potential compared with the non-fertilized plants during the early growth period before N fixation could adequately compensate for any deficiency in the supply of available N from the soil.

Symbiotic N fixation apparently was not the only means whereby fababeans, in large measure, were able to compensate for N deficiency at the lower rates of applied N. Despite a threefold increase in N uptake by barley in response to applied N (Table 3.3), NO_3-N in the top 48 inches of soil at harvest was appreciably higher under barley than under fababeans at all rates of applied N (Table 3.5). Since this discrepancy was apparent only below the top 12 inches of soil and in view of the similarity in the % crop use of applied N for both crops (Table 3.4), it was concluded that fababeans were better able to exploit the subsoil NO_3-N.

Concerning the measurement of symbiotic N fixation, the acetylene reduction method underestimated the amount of N fixed during the growing season by at least 50% compared with the difference method estimates. This agrees with previous findings in the Soil Science Department at Saskatoon. Although the former method allowed determination of values for N fixation at intervals during the season (Figure 3.1), it required considerably greater input of manpower, sophisticated equipment, etc. The simpler difference method should give a satisfactory estimate of the total amount of symbiotically fixed N present in the above ground plant material provided that crop use of soil and fertilizer N is substantially the same for all crops at a given site at a given level of soil fertility. In this study, the ^{15}N data (Table 3.4) indicated that this condition was met with regard to % crop use of the applied N and presumably with regard to crop use of available soil N present in the same volume of soil as the fertilizer. There was some difference in crop exploitation of subsoil NO_3-N by the two crops as mentioned in the previous paragraph. This was allowed for when calculating fababean N fixation by difference (Table 3.6).

The full potential for symbiotic N fixation by a properly inoculated and seeded fababean crop grown on soils of adequate fertility and moisture regime in the prairies is probably greater than the values reported in this study for two reasons. Firstly, the crop had to be harvested after a growing season of only 90 days when the rate of symbiotic N fixation was at its maximum. Fababean varieties presently licenced for Saskatchewan all require 112 to 114 days to reach maturity. Secondly, no estimate was made of the quantity of fixed N in the fababean roots.

The fact that the application of inorganic P fertilizer to fababeans resulted in only a small non-significant increase in total D.M. yield and an actual decrease in bean yield (Table 3.8) is difficult to reconcile with the $NaHCO_3$ extractable P data. This data indicated that the unfertilized Hoey soil was low in plant available P. The statistically significant increases in bean and straw P content and in total P uptake due to applied P also indicated that the soil was low in available P.

According to the ^{32}P fababean data (Table 3.9) between 11 and 17% of the applied P was recovered in the above ground plant material. These values, when expressed as % crop use of applied P in the bean tissue alone, were similar to comparable values from the 1973 fababean summerfallow experiment[5]. In the latter experiment, maximum increases above the check yield of 60 and 40% were recorded for bean and total D.M. yields respectively at the maximum rate of application of 90 lb P_2O_5/acre. This was in a soil that initially contained 12 lb P/acre $NaHCO_3$-extractable P in the top 6 inches.

This discrepancy in fababean yield response to applied P in 1973 and 1974 may have been due to the inability of the $NaHCO_3$ soil test procedure to predict the P requirement of fababeans under different soil and climatic conditions. The whole question of evaluating the P supplying power of a soil has been examined in detail in a recent review paper[6].

It is also possible that placing P fertilizer with the seed in the 1974 experiment had an adverse effect on germination and seedling development of fababeans, or on some aspect of symbiotic N fixation. There was certainly evidence of yield depression for the 60 lb P_2O_5/acre treatment where crystalline ^{32}P-labelled fertilizer was substituted for the granular form (Table 3.8). This would probably explain why phosphorus 'A' values were not independent of the rate of P application (Table 3.9). Whether the yield depression was due to a salt effect resulting from the use of crystalline material or was due to the presence of the radioisotope ^{32}P is uncertain.

The adverse effect of moderate to high rates of seed-placed P on early development of non-leguminous crops such as rapeseed under prairie conditions has been shown in studies comparing seed placement and side-banding of P[7]. However, according to the 1973 fababean data for yield and crop use of applied P, there was little difference between the two methods of P application at rates up to 90 lb P_2O_5/acre[5]. The important difference between the 1973 and 1974 fababean experiments was that in the former, there was no evidence of symbiotic N fixation by the fababeans. This leads to the suggestion that in the 1974 experiments, the detrimental effect of crystalline ^{32}P labelled fertilizer on yield and probably the overall poor fababean yield response to applied P was due to the adverse effect of seed-placed P on symbiotic N fixation.

Conclusions

1) In the Prairie Black Soil zone, properly inoculated fababeans, given adequate soil moisture and P fertility levels, have the capability of fixing appreciable quantities of atmospheric N--probably in excess of 130 lb N/acre/season.

2) Moderate applications of inorganic N (50 lb N/acre or less) on an initially N deficient soil should have a beneficial effect on fababean dry matter and protein yield without adversely affecting N fixation. More information is required concerning the relationship between levels of inorganic N in a soil and the rate of symbiotic N fixation.

3) The effect of the soil P fertility level on fababean yield is unclear at this stage. Indications are that fababeans grown on P deficient soils under normal prairie climatic conditions will probably respond to applied inorganic P provided that the crop has an adequate supply of soil and fertilizer N. However, where there is active symbiotic N fixation, fababean response to fertilizer P when applied with the inoculated seed is likely to be small. Further studies should be made of the effect of method of P application on yield and N fixation capacity of fababeans.

References

1) Agriculture TKN BD40 Block Digestor Method (1974) and AutoAnalyzer II Industrial Methods 325-74W (1974) and 94-70W (1973). Technicon Industrial Systems, Tarrytown, N.Y.

2) Rennie, D.A. and Paul, E.A. 1971. Isotope Methodology and Techniques in Soil-Plant Nutrition and Plant Physiology. Sask. Inst. of Pedology Pub. No. 76.

3) Steel, R.G.D. and Torrie, J.M. 1960. Principles and Procedures in Statistics. McGraw-Hill, N.Y.

4) Paul, E.A., Vlassak, K. and Myers, R.J.K. 1973. Nitrogen fixation. CCIBP Tech. Rept. No. 31.

5) McGill, K.S. 1975. Studies on the N and P nutrition of fababeans. In 1973 Soil-Plant Nutrient Research Report. Sask. Inst. of Pedology Report No. M25. pp. 121-145.

6) Sadler, J.M. and Stewart, J.W.B. 1974. Residual fertilizer phosphorus in Western Canadian soils: a review. Sask. Inst. of Pedology Pub. No. R136.

7) Ukrainetz, H. - Private communication.

4. APPENDICES

APPENDIX A. Selected tables of data from the fababean experiment (Section 3).

Table A1. Effect of applied N and P on fababean dry matter yields (lb/acre).

lb N/acre \ lb P_2O_5/acre	0	15*	30*	60*	60	90
Beans						
0	1470	1560	1430	1270	1590	1520
25	1710	1700	1660	1300	1600	1630
50	1920	1810	1800	1510	1610	1650
100	2050	1990	1850	1600	1940	1950
Total						
0	7410	7800	7330	7180	7880	7890
25	7830	7650	8300	7460	8300	8460
50	7830	8290	8360	7400	8470	7800
100	8030	8270	8030	7950	8050	9190

Table A2. Effect of applied N and P on fababean tissue N content (%).

lb N/acre \ lb P_2O_5/acre	0	15*	30*	60*	60	90
Beans						
0	5.80	5.65	5.63	5.79	5.69	5.70
25	5.65	5.61	5.61	5.58	5.66	5.61
50	5.53	5.51	5.57	5.47	5.58	5.52
100	5.49	5.43	5.55	5.57	5.52	5.60
Straw						
0	1.62	1.49	1.49	1.40	1.33	1.36
25	1.42	1.43	1.29	1.43	1.47	1.52
50	1.27	1.31	1.37	1.21	1.52	1.43
100	1.27	1.19	1.24	1.28	1.31	1.31

*P treatments receiving crystalline ^{32}P-labelled 12-60-0 not granular 11-55-0.

Table A3. Effect of applied N and P on fababean N uptake (lb N/acre).

lb N/acre \ lb P_2O_5/acre	0	15*	30*	60*	60	90
Beans						
0	85	88	80	73	90	87
25	96	95	93	72	91	91
50	106	100	100	82	90	91
100	112	108	102	90	107	109
Total						
0	181	178	167	157	173	174
25	183	180	178	160	189	194
50	183	185	188	153	195	180
100	188	183	179	171	187	204

Table A4. Effect of applied N and P on fababean tissue P content (%).

lb N/acre \ lb P_2O_5/acre	0	15*	30*	60*	60	90
Beans						
0	.67	.66	.66	.73	.71	.73
25	.63	.65	.66	.70	.68	.70
50	.62	.64	.67	.68	.69	.67
100	.56	.57	.63	.66	.64	.68
Straw						
0	.175	.146	.151	.149	.151	.161
25	.095	.129	.128	.148	.139	.165
50	.112	.123	.130	.131	.154	.153
100	.082	.078	.097	.114	.127	.127

*P treatments receiving crystalline ^{32}P-labelled 12-60-0 not granular 11-55-0.

Table A5. Effect of applied N and P on fababean P uptake (lb P/acre).

lb N/acre \ lb P_2O_5/acre	0	15*	30*	60*	60	90
Beans						
0	9.8	10.0	9.4	9.2	11.2	11.1
25	10.7	11.0	10.9	9.0	10.9	11.4
50	12.0	11.6	11.9	10.3	11.0	11.0
100	11.4	11.2	11.6	10.6	12.5	13.1
Total						
0	20.2	19.0	18.3	18.1	20.6	21.2
25	16.4	18.6	19.4	18.0	20.2	22.6
50	18.6	19.6	20.2	18.0	21.7	20.5
100	16.3	16.0	17.6	17.7	20.3	22.4

Table A6. Effect of applied N and P on total crop use of applied P (%).

lb N/acre \ lb P_2O_5/acre	15*	30*	60*
0	18.1	13.1	10.5
25	17.2	16.4	12.1
50	14.9	13.0	10.0
100	16.8	15.2	12.3

Table A7. Effect of applied N and P on phosphorus 'A' values (lb P/acre).

lb N/acre \ lb P_2O_5/acre	15*	30*	60*
0	99	128	147
25	102	105	123
50	139	144	162
100	93	105	120

*P treatments receiving crystalline ^{32}P-labelled 12-60-0 not granular 11-55-0.

APPENDIX B. Legal location and soil type of experimental field plots for 1974 irrigation trials.

Farmer Co-operator	Crop Investigated	Legal Location	Soil Type
M. Cameron	Barley	SE27-29-8 W3	Asquith: vl
	Soft Wheat		
	Rapeseed		
A. Pederson	Barley	NW21-28-7 W3	Elstow: 1
	Soft Wheat		
	Rapeseed		
	Corn	NW20-28-7 W3	Elstow: 1
P.F.R.A.	Potatoes	SW15-29-8 W3	Bradwell: vl

APPENDIX C. Legal location and soil type of experimental field plots for 1974 nitrogen trials.

Farmer Co-operator	Crop Investigated	Legal Location	Soil Type
M. Booker	Barley	SW28-32-2 W3	Weyburn: 1
L. Johns	Barley	NE19-33-28 W2	Elstow: Sicl
V. Lindstrum	Barley	SW4-35-13 W2	Yorkton: 1
Wm. Minky	Barley	SW4-38-10 W2	Waitville: 1
S. Njaa	Barley	SE5-45-25 W2	Hoey: cl
A. Pank	Barley	NW33-38-20 W2	Naicam: 1
	Wheat		
	Rapeseed		

APPENDIX D. Legal location and soil types of experimental field plot for 1974 fababean trial.

Farmer Co-operator	Crop Investigated	Legal Location	Soil Type
S. Njaa	Fababean	SE5-45-25 W2	Hoey: cl

5. SELECTED PAPERS

5.1 Wheat Yields and Fertility Response as Affected by Climate (by K.B. MacDonald)

The affects of climate on wheat production are many and varied. It is not the purpose of this report to present an exhaustive discussion on this subject but rather to examine some of the data for Saskatchewan and point out some of the ways in which wheat production is affected by climate. The following aspects of wheat production will be considered:

(i) production on fallow and stubble land

(ii) production on various soil types

(iii) production on various soil types under various fertility treatments

Yield and Climatic Data and Its Sources

In the initial phase of this project, climatic data from twelve meteorological stations was summarized. The stations chosen are shown in Fig. 1. These stations were selected because they occur throughout the broad climatic regions of the province and they had reasonably reliable long-term records. Later in the study, the records from Melfort and Scott were included.

A general picture of crop yields across the province was obtained from Statistics Canada summaries. Since 1964, Statistics Canada has collected, on a sub-crop district basis, the yields of wheat, oats, barley, flax and rapeseed. This data has been summarized as yield of these crops on fallow and on stubble. This data provides no indication of soil type, fertility levels or management levels under which yields were obtained but does give a general picture of yields.

The Sanford and Evans compilation of wheat yields by delivery points and as summarized by Dr. H.C. Moss was examined to get an indication of wheat yields on a narrow range of soil types. This data covers the period from 1931 to 1961 and for the purpose of this study only data from 1941 to 1961 were used. This was done so that these data would cover a time period for which meteorological summaries were available. These yields represent estimates in which crop yields on fallow land are not distinguished from those on stubble and there is no indication of management or fertility levels under which they were obtained. They do, however, constitute yields from a relatively localized area of fairly uniform soil type.

The third source of yield data is from the University and Research Station trials. These were obtained from the data bank of the Soil Testing Laboratory. These yields are actual measured values of localized studies where the soil type is known and fertilizer application is documented. The level of management associated with these yields was assumed to be good.

WHY DISCUSS WHEAT?

Wheat is the crop of major economic importance in this province and hence has received much of the research attention. Furthermore, from the yield summaries compiled by Statistics Canada, it is possible to get an indication of how closely the yield of other crops was reflected in the yields of wheat. Simple linear correlations were run between all crops for all crop districts in Saskatchewan for the years 1964 to 1972 inclusive (table 1). From these comparisons, it was readily apparent that the three cereals, wheat, oats and barley behaved similarily to each other whether grown on stubble or on fallow land (minimum r value obtained between yields of cereals was 0.88 between wheat grown on fallow and barley grown on stubble. It was also quite apparent that rapeseed and flax respond to the environmental conditions quite differently than cereals and also quite differently to each other (table 1 and 2).

WHEAT YIELDS AS AFFECTED BY CLIMATE - PROVINCIAL PERSPECTIVE

In order to assess the affects of climatic variations across the province on wheat yield, regression analysis was carried out. This was done using the annual data summarized for the twelve meteorological stations and the wheat yields from the sub-crop districts in which they are located. It is realized that the yield estimates from Statistics Canada are over the relatively large area of a crop district while the climatic information has been collected at a particular point location within the sub-crop district. It was assumed that the yield estimates obtained from Statistics Canada are reasonably accurate and that the climatic data could be generalized to give an index of climatic conditions over the sub-crop district.

Stepwise multiple regression analysis was carried out using yield as the dependent variable and climatic variables as independent variables. The climatic variables included growing degree days above 42° F for the months of May, June, July and August, precipitation over the growing season (May 10 to Aug. 7) for the winter prior to seeding (November 1 to Apr. 30) for the summer prior to seeding (May 1 to Oct. 31 for fallow seeded crops and Aug. 1 to Oct. 31 for stubble seeded crops) for the winter prior to the summer of fallow and for the fall period prior to fallow year. Included also was a measure of periods of moisture stress early in the season, in the middle of the growing season and towards the end of the season.

On a provincial basis, rainfall during the growing season was the variable selected as explaining the largest amount of the yield variation for both yields on stubble r= .63 and yields on fallow (r=.55). At step five of the regression, the multiple correlation coefficient was r=0.76 for fallow and r=0.72 for stubble. The other variables in the equation at step five were stress throughout the season, May and June growing degree days, the precipitation in the fall prior to harvest for the fallow seeded crop; and moisture stress in early and mid-season, May growing degree days, and precipitation in the previous fall for the stubble seeded crop.

A similar analysis was carried out for rapeseed yields and in this case the first variable to enter the regression was moisture stress early in the season for the fallow seeded crop and August growing degree days for the stubble seeded crop. By step five of the regression, growing season rainfall had not been entered as a variable. At this step, the multiple correlation coefficient was 0.77 for fallow seeded rapeseed and 0.79 for stubble seeded rapeseed.

With flax on a provincial basis growing season rainfall was an important factor in determing the yield on stubble but not on fallow.

In general, the regression model at step five was effective in explaining more than 50% (r^2 = 0.50) of the observed yield variation on a province-wide basis for all crops except flax grown on stubble where only 38% was explained (r^2 = 0.38).

A second approach taken on a provincial basis was to concentrate on crop yields as affected by moisture. The source of moisture was taken as all the precipitation occuring from the time of harvest of the previous crop up to and including precipitation during the growing season of the crop. For fallow seeded crops, this was a 24-month period while for stubble seeded crops, it was a 12-month period. The relative importance of precipitation in the various periods was determined by carrying out a multiple regression of crop yield versus the amounts of precipitation over various periods. The coefficients of the regression were then used to weight the precipitation over the time of storage and growth and the resultant weighted values were summed to give a measure of the overall amount of moisture available to a given crop. In addition, this weighted value was divided by the growing degree days above 42° F during the growing season. This figure gives some indication of the actual amount of moisture available for crop use in relation to the possible demand as expressed by growing degree days. The wheat yields across the province versus this moisture use index are presented in figure 2. Generally, the trend illustrated shows that wheat yield is strongly related to moisture use at low values but, as moisture increases, the yield becomes less dependent and tends to plateau.

The trend lines shown on figure 2 have been fitted to the data by regression analysis. They show a striking difference of five to eight bu/acre between the yields of stubble and fallow seeded crops in the region where yields are relatively independent of moisture use. It appears likely then that this yield difference is caused by some factor other than moisture. Some of the possible reasons for this difference may be difference in seedbed preparation, date of seeding or fertility levels.

WHEAT YIELDS AND FERTILITY RESPONSE AS AFFECTED BY CLIMATE - LOCALIZED STUDIES

Data from the Agriculture Canada Research Station and the Department of Soil Science was examined with a view to comparing yields of wheat seeded on stubble and fallow land under conditions of good management where the fertility treatments were known. In order to relate these yields to climate, the trials selected were only those within ten miles of a climate station. This severely restricted the number of trials available for this comparison. The source of this data was from the data bank of the Soil Testing Laboratory which covers the period up to and including 1969.

For an initial look at this data, two levels of fertility were selected - the check yield values and the yields under general fertilizer recommendations i.e. 20 lb. P_2O_5 /acre on fallow and 20 lb. N and 20 lb. P_2O_5/acre on stubble seeded crops.

Again, stepwise multiple regression analysis was carried out using yield as the dependent variable and climatic seeded crop, growing season rainfall was the most important variable in explaining the yield variation followed by moisture stress early in the growing season. On the fallow seeded crop, the climatic variable which explained the most of the yield variation was the precipitation in the first fall and winter of the fallow period; growing season rainfall was the second most important variable.

It is interesting to examine average yields and average yield responses to applied fertilizer on these data. The check yields of wheat seeded on stubble were 20.0 $\pm$ 6.2 bu/acre and 24.7 $\pm$ 9.7 for wheat seeded on fallow. These yields and the differences between stubble and fallow seeded crops were similar to the average on a provincial basis. When the crop was fertilized at general recommendations, the average yield of stubble seeded crops increased only slightly to 21.2 ± 6.1 bu/acre while the yield of wheat seeded on fallow increased almost 5 bu/acre to 29.3 ± 11.0 bu/acre.

This variable fertilizer response is not surprising when it is considered that these data include trials from across the province, or widely varying climatic zones and over a variety of soil types and textures. The native fertility status of the soil also was not considered in this analysis because, for a number of the trials, it was not available.

To get some indication of the effects of soil type on the fertility response, soils of a similar texture were grouped. Figure 3 shows the yield response for wheat seeded on stubble on loam textured soils fertilized at the rate of 40 lb. N and 20 lb. P_2O_5 per acre. The results are plotted against growing season rainfall. These data are quite limited and include observations from the Swift Current area, the Scott area and the Waseca area. Within this limited amount of data, it appears that the fertility response is dependent on growing season rainfall for loam textured soils. In contrast, the fertilizer response on clay and heavy clay soils showed no real trend with increasing rainfall during the growing season. Possibly the actual spring seeding conditions or some climatic variable other than growing season rainfall is more important in influencing fertilizer response on these soils.

WHEAT YIELDS IN RELATION TO SOIL TYPE - LOCALIZED BASIS

The yield compilations of Dr. H. C. Moss from the Sanford & Evans yield estimates were examined to get some insight into the effect of soil type on wheat yields. The data selected were those delivery points situated within a common soil type and located close to one of the meteorological stations. These restrictions limited the number of soil types which were available. It was possible to select soils in the areas of Nashlyn, Kindersley, Estevan, Saskatoon and Waseca. Most of these soils were of solodized solonetz, with some solod and solonetz of loam to clay-loam texture on level to undulating typography. The wheat yields for each soil type were combined with climatic data from the adjoining weather station in a stepwise regression model.

In the regression model, the wheat yields in the Brown soil zone (Kindersley and Nashlyn) showed a strong dependence on climate, (r values ranged from 0.74 to 0.91 over 4 soil types). In the Dark Brown and Black soil zones, relationship was not as well defined (r values ranged from 0.54 to 0.78).

In the Kindersley area, it was possible to determine the climate parameters which affected the wheat yields on soils of a clay to heavy clay texture. On these soils, the first variable brought into the regression was moisture stress throughout the growing season. Other variables included at step five of the regression were June and July growing degree days, stress late in the growing season and precipitation during the winter prior to seeding. This finding lends support to the previous observation that fertility response was not closely related to growing season rainfall on clay textured soil.

A striking feature of these analyses was that in general the most important climatic parameter affecting yields on the solodized-solonetz soils was the amount of rainfall in the summer and fall prior to seeding. A trend such as this should provide a farmer on this soil type with a firmer base on which to make management decisions.

SUMMARY

As with most discussions of this subject, the data used has been of an historical nature and has not been collected for this purpose. It is generally lacking in both scope and specificity. I do not claim, however, to have exhausted the sources of data available but I have presented some trends which are emerging from the data. These should be followed up with more data to determine whether the trends are real or merely artifacts resulting from limited data.

From these analyses, the difference between the yields of crops seeded on fallow and on stubble is quite apparent and not necessarily related to the amount of moisture available to the crop. It is of real economic importance to determine what factors do, in fact, cause this yield difference. The results presented here suggest that any study of the factors restricting yields on stubble crops should be on the basis of specific soil types.

It may be that other climatic factors such as moisture stress or periods of high temperature during critical growth periods may be involved. In this case, seeding dates for the crop in relation to the type of growing season should give some information on this. It may well be that particular soil types or particular areas will require slightly delayed or very early seeding dates to achieve the best yields with the prevailing climate.

Fertilizer response as it is affected by climate may well depend on soil type.

The overall conclusion from this study is that it is of extreme importance to bring the data bank of the Soil Testing Laboratory up to date and make it as complete as possible. When this is done, hopefully, much of the information necessary to either expand and confirm some of the trends described here or reject them will be available. As far as possible, any further studies also should be related to soil type and climate - not just growing season climate, but climate throughout the full year.

TABLE 1. CORRELATION COEFFICIENTS FOR YIELDS OF VARIOUS CROPS IN THE 9-YEAR PERIOD 1964-1972

		FALLOW				STUBBLE			
		WHEAT	OATS	BARLEY	FLAX	WHEAT	OATS	BARLEY	FLAX
FALLOW	WHEAT	1.00	0.90	0.93	0.76	0.92	0.87	0.88	0.72
	OATS		1.00	0.95	0.79	0.90	0.95	0.91	0.75
	BARLEY			1.00	0.80	0.91	0.92	0.94	0.77
	FLAX				1.00	0.75	0.78	0.78	0.78
STUBBLE	WHEAT					1.00	0.92	0.93	0.75
	OATS						1.00	0.94	0.77
	BARLEY							1.00	0.77
	FLAX								1.00

TABLE 2. CORRELATION COEFFICIENTS FOR YIELDS OF WHEAT, RAPESEED AND FLAX FOR SASKATCHEWAN CROP DISTRICTS 5-9.

		FALLOW			STUBBLE		
		WHEAT	FLAX	RAPESEED	WHEAT	FLAX	RAPESEED
FALLOW	WHEAT	1.00	0.76	0.66	0.93	0.63	0.41
	FLAX		1.00	0.42	0.69	0.50	0.27
	RAPESEED			1.00	0.63	0.40	0.52
STUBBLE	WHEAT				1.00	0.66	0.38
	FLAX					1.00	0.14
	RAPESEED						1.00

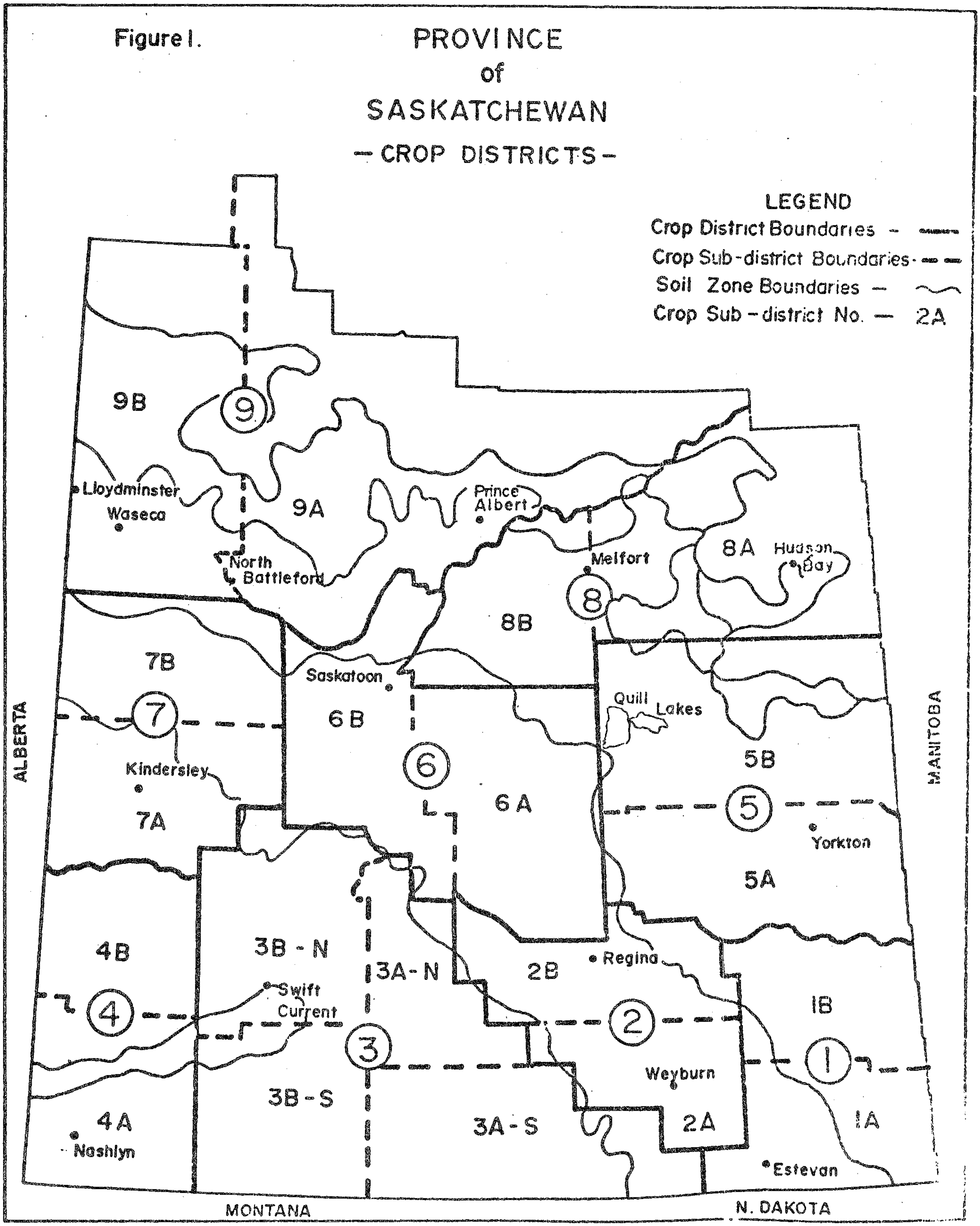


Figure I. PROVINCE of SASKATCHEWAN — CROP DISTRICTS —

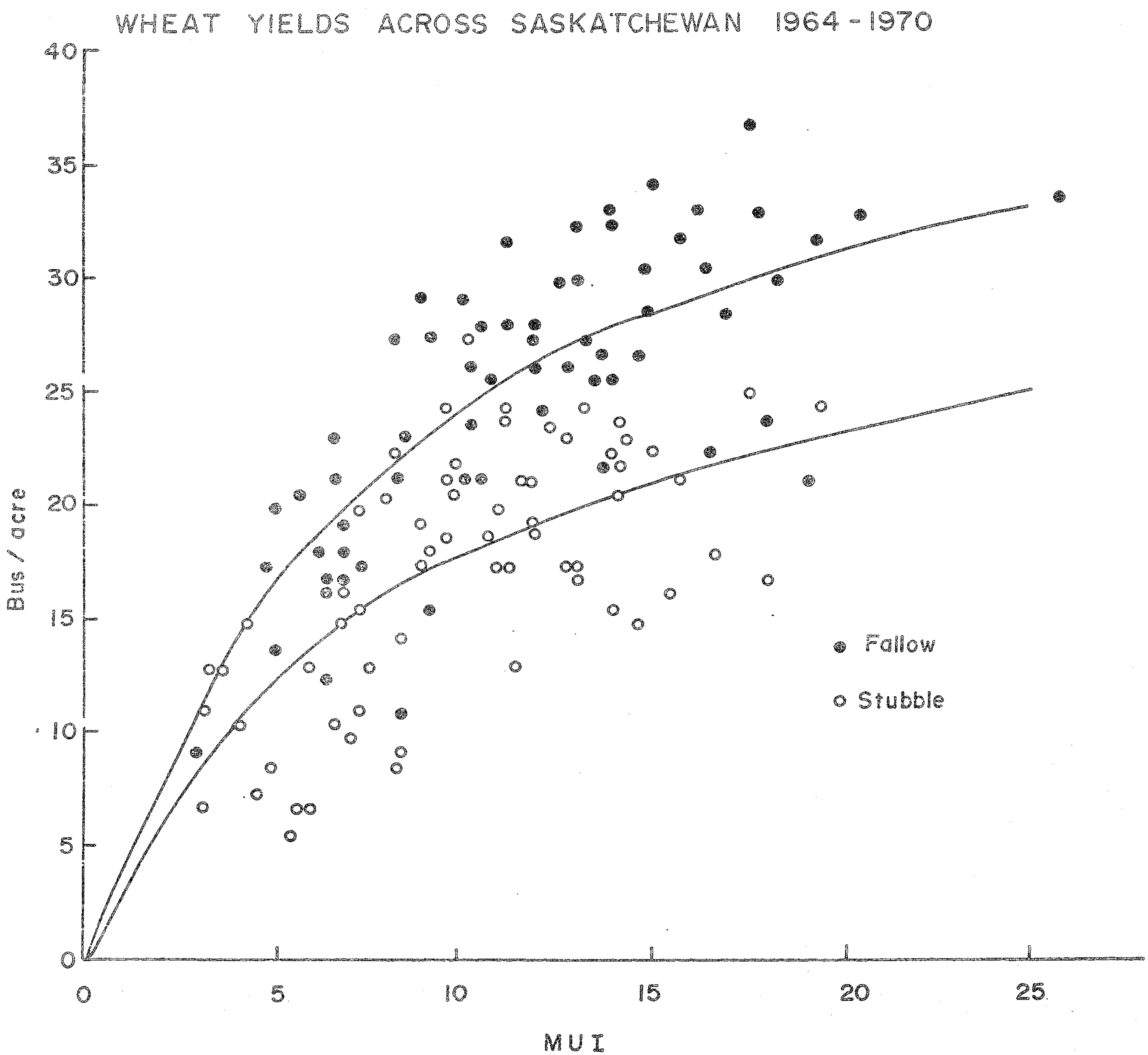


Figure 2: Relationship between wheat yields at 10 sub-crop districts across Saskatchewan and a moisture use index (MUI)

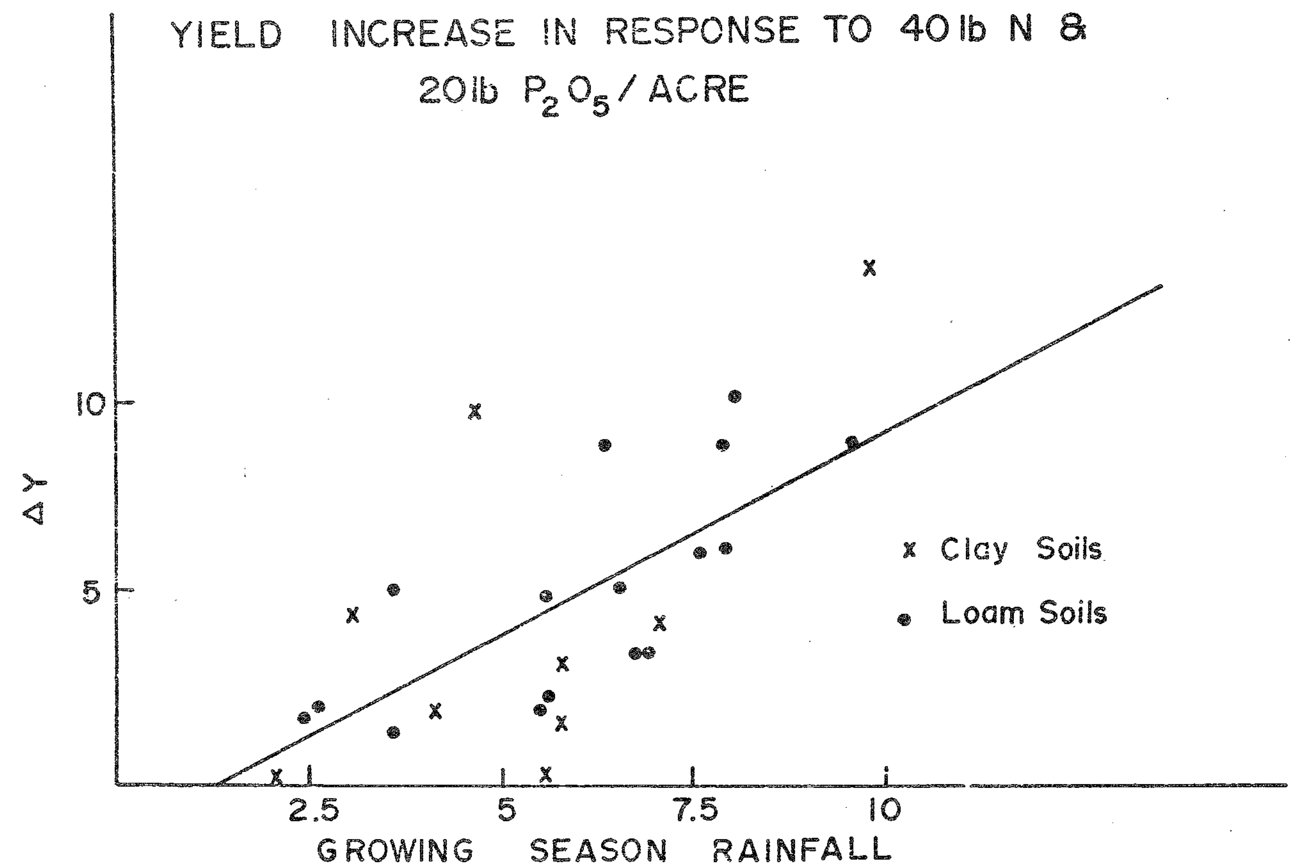


Figure 3: Yield increase of wheat on stubble land versus rainfall during the growing season.